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Technical Report 11-TR

ENGINEERING TEST REPORT; LIGHTWEIGHT GYRO AZIMUTH THEODOLITE (LEAR NORTH-SEEKING GYRO MODEL NO. 11NG530A)

USAEGIMRADA Task 1S643315D57811

USATECOM Project 2-S-3020-01

21 February 1963

U.S. ARMY
GEODESY, INTELLIGENCE AND MAPPING
RESEARCH AND DEVELOPMENT AGENCY
CORPS OF ENGINEERS

FORT BELVOIR VA

U. S. ARMY ENGINEER
GEODESY, INTELLIGENCE AND MAPPING RESEARCH AND DEVELOPMENT AGENCY
FORT BELVOIR, VIRGINIA

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THE VIEWS CONTAINED HEREIN REPRESENT ONLY THE VIEWS OF THE PREPARING AGENCY AND HAVE NOT BEEN APPROVED BY THE DEPARTMENT OF THE ARMY.

PREFACE

The investigations and tests reported herein were conducted under the authority of Task 8T35-10-001-11 (changed to Task 1S643315D-57811, 1 January 1963), "Inertial Surveying Equipment." A copy of the project card is included as Appendix A to this report.

Work on this project was accomplished by Mr. R. T. Flowe with assistance from Messrs. D. C. Bright, C. L. Heidler, and C. C. Johnson. The evaluation and tests were performed under the supervision of Mr. O. W. Bowker, Chief, Surveying Systems Branch, and Mr. M. C. Shetler, Chief, Surveying and Geodesy Division.

CONTENTS

SUMMARY

This report covers the Engineering Tests of the Lightweight Gyro Azimuth Theodolite, Lear Model No. 11NG530A, performed at the GIMRADA test areas at Fort Belvoir, Virginia, and Fort Greely, Alaska. The test instrument was fabricated by Astronics Division of Lear Siegler, Inc., and consists of a theodolite mounted on a gyroscopic reference unit, a combined electronic control unit and carrying case, and a tripod. The instrument is powered by internal batteries, weighs 31 pounds 6 ounces, and after 20 minutes operation time will permit readout of azimuth to any target sighted through the theodolite telescope. Testing under various conditions demonstrated that accuracies of 0.38 mil (standard deviation) or better could be obtained with the instrument.

The report concludes that the Lightweight Gyro Azimuth Theodolite (Lear) meets the objective and Military Characteristics set forth in Task 1S643315D57811 for short range weapons orientation except as noted in Appendix E, and upon correction of the deficiencies listed in Appendix D, the Lightweight Gyro Azimuth Theodolite (Lear) will be suitable for military field use.

ENGINEERING TEST REPORT; LIGHTWEIGHT GYRO AZIMUTH THEODOLITE (LEAR NORTH-SEEKING GYRO MODEL NO. 11NG530A)

I. INTRODUCTION

1. Subject. This report covers the development and testing of a Lightweight Gyro Azimuth Theodolite. The test instrument consists of a theodolite mounted on a north-seeking gyrocompass base called the gyroscopic reference unit. The purpose of the instrument is to provide the true azimuth of any target sighted through the theodolite telescope.

2. Background.

a. The general requirement for improved all-weather equipment for extending survey control in support of military operations has led to rapid advances in the development of improved equipment for distance measurement. To keep abreast of this advanced capability, it has become necessary to develop new methods for obtaining accurate azimuths day or night under all weather conditions. Such equipment could provide artillery and missile launching units with a rapid means for determining azimuth in any tactical situation and could expedite survey operations.

b. As a means of satisfying this need, the Corps of Engineers has been following the development of inertial systems under the authority of Task 8T35-10-001-11, "Inertial Surveying Equipment." An investigation initiated early in 1956 revealed that the utilization of gyroscopic devices for surveying had been a subject of interest to German scientists as early as 1921; equipment fabricated at that time utilized ship gyrocompass components and resulted in equipment unsuited for field use. The feasibility of such instruments, however, was demonstrated. The investigations resulted in a belief that militarized versions of foreign or domestic gyro equipment could provide a gyro azimuth device of sufficient accuracy with a minimum observing time to be utilized for azimuth determination in artillery surveying and weapons orientation.

c. In 1957, the Autonetics Division of North American Aviation, Inc., demonstrated to technical agencies an instrument called the Autonetics Baseline Equipment (ABLE). Based upon these demonstrations, a contract was awarded to Autonetics by Frankford Arsenal for a militarized ABLE with a Wild T-2 theodolite readout. A determination by the Chief of Research and Development subsequently assigned responsibility to the Corps of Engineers for the development of this type of instrument. The Ordnance contract with Autonetics was transferred to Geodesy, Intelligence and Mapping Research and Development Agency (GIMRADA), and in November 1958, the ABLE instrument was delivered to Fort Belvoir for Engineering Tests.

d. Tests of the ABLE system by GIMRADA and by the service test organization found the instrument to be suitable for artillery use. Type classification procedures were initiated, and CETC action in October 1959 classified the instrument as standard A under the title of "Surveying Instrument, Azimuth: Gyro; Artillery." Production of this instrument is now underway and the first units were delivered in early 1962.

e. In 1960, an effort was initiated to develop a lightweight gyro azimuth theodolite having an accuracy capability suitable for short range weapons orientation. The complete instrument was to be designed for backpacking by one man. After competitive bidding, a contract was awarded to Lear, Inc., Astronics Division, for design and fabrication of the instrument.

f. The Autonetics Division of North American Aviation, Inc., which also submitted a proposal on the lightweight gyro azimuth theodolite development, undertook a company funded development program based on the Army requirements for this instrument. The Autonetics effort resulted in delivery of the Miniaturized Autonetics Baseline Equipment (MABLE) on 24 July 1961 for tests and evaluation by GIMRADA under the terms of a release agreement. Engineering Tests of the MABLE were completed by GIMRADA during the latter half of 1961, and a draft Engineering Test Report was prepared. This report concluded that the MABLE instrument met the objectives and Military Characteristics set forth in Task 8T35-10-001-11 for short range weapons orientation and would be suitable for field Army use after correction of deficiencies. Upon completion of the Engineering Tests, MABLE was delivered to the U. S. Army Artillery Board for evaluation.

g. The Lear instrument was delivered to GIMRADA in March 1962; a second unit built by Lear with company funds was released to the Artillery Board for their concurrent tests.

II. INVESTIGATION

3. Description.

a. The Lear Lightweight Gyro Azimuth Theodolite is a portable, battery powered instrument consisting of a lightweight theodolite mounted on a gyroscopic reference unit, a combined carrying case and electronic control unit, a tripod, and a backpack. Photographs in Appendix B (Figs. 3 through 12) show the various components and the assembled system.

b. The gyroscopic reference unit (Figs. 3 and 6) consists basically of a Kern DKM-1 mil scale theodolite mounted on a housing which contains a band suspended gyroscope, electrical pickoff and damping elements, and a servomechanism.

c. The instrument carrying case (Fig. 9) contains the power pack and control panel (Fig. 7). The power pack includes the 24-volt battery supply (Fig. 4) and the static inverter (Fig. 5). Space is provided on the battery panel for a plumb bob and theodolite accessories.

d. The gyroscopic reference unit is secured to the tripod by the three clamps shown extended in Fig. 8. The circular mounting plate of the tripod allows one-half inch lateral movement of the gyroscopic reference unit to permit easy plumbing. Coarse and fine leveling adjustments are provided for each leg of the tripod.

e. The backpack (Fig. 11) is a Wild T-3 back harness modified to receive the instrument carrying case as shown in Fig. 12.

4. Principle of Operation.

a. The Lightweight Gyro Azimuth Theodolite makes use of two basic dynamic characteristics of a gyroscope: (1) The ability of an undisturbed gyroscope to maintain its orientation with respect to inertial space (celestial sphere), and (2) the tendency of a gyroscope to precess, when disturbed, about an axis that is parallel to the direction from which the disturbance is applied.

b. The gyroscope, in the test instrument, is suspended from the instrument housing with its axis of spin horizontal by a thin metal band. The weight of the gyroscope causes the pendulous system to act as a plumb bob with the suspension band defining the local vertical.

c. Referring to Fig. 1(a) and assuming that the angular momentum vector of the gyroscope is pointed east, as the earth rotates toward (b), the gyroscope attempts to maintain its orientation in inertial space. This requires that the suspension band depart from the local vertical as shown in (b) as the earth rotates. The acceleration of gravity acting on the mass center of the pendulum produces a torque about a horizontal axis at right angles to the

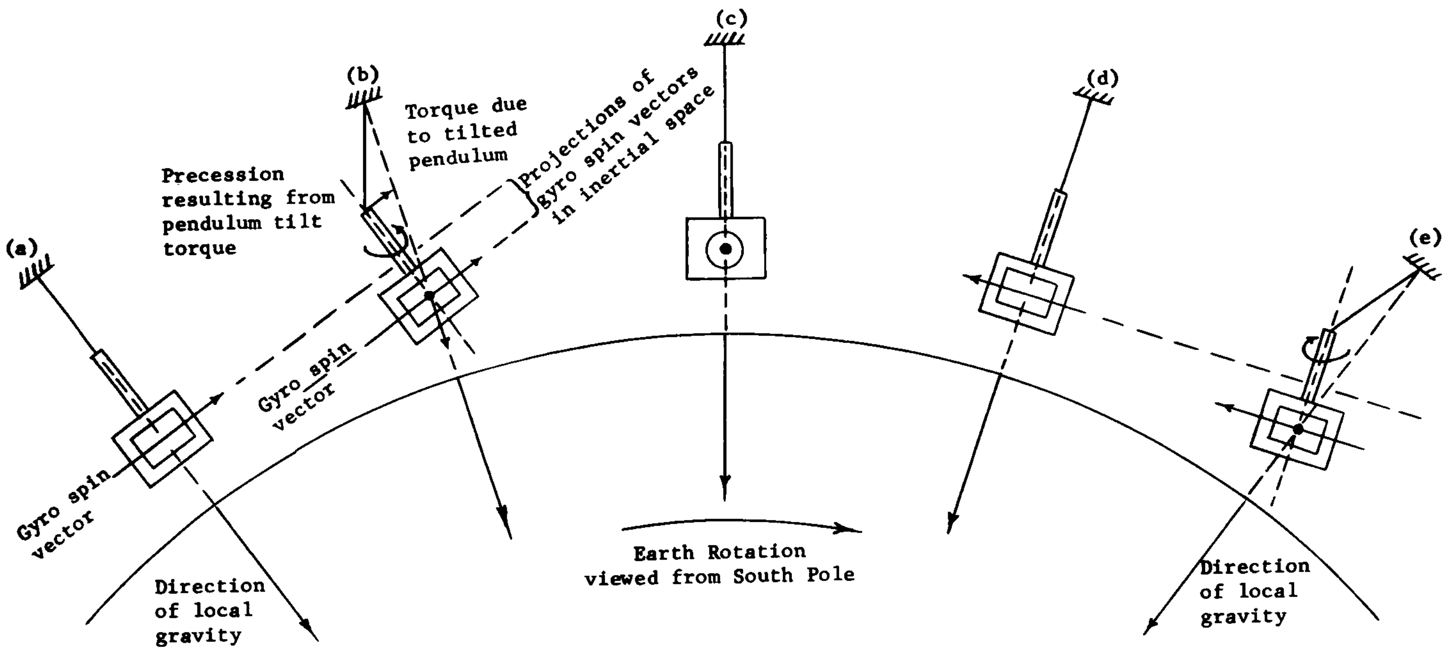

Fig. 1. Principle of Lightweight Gyro Azimuth Theodolite.

spin axis. In accordance with the laws of gyroscopic precession, this torque produces a turning rate, or precession, about the vertical axis until position (c) is reached and the spin axis points north. In this orientation, the earth can rotate without causing further precession, since all of its rotation is around the spin axis of the gyroscope. The gyroscope, however, has built up momentum in precessing toward north, and this momentum carries it past north to position (d). At position (e), the same sequence occurs as at (a), but since the angular momentum vector is now pointing west, precession drives the spin axis back toward north.

d. The pendulous system, if undamped, will continue to oscillate about north in this manner. North can be determined by averaging the peaks of the oscillations, but in the Lightweight Gyro Azimuth Theodolite, electrical damping is introduced to cause the gyroscope to settle in the north direction, thus simplifying azimuth determination.

e. Figure 2 shows a simplified cross section of the gyroscopic reference unit. When uncaged for operation, the gyro container hangs freely from the suspension band. Electrical power to operate the gyroscope is supplied through two power transfer bands which are carefully arranged to cause minimum mechanical interference with gyroscopic precession.

f. Gyroscopic precession is detected by means of electrical devices called pickoffs which generate an electrical signal proportional to the angular motion of the gyroscope. The signal is amplified and applied to a null meter which is used as a reference in damping gyroscopic oscillations about north.

g. Final north orientation occurs when the null position of the suspension band (untwisted position) is attained and gyro oscillations due to earth rotation are damped. To accomplish this, the operator maintains the null meter indicator at the zero position by manipulating a two-way electrical switch. This switch supplies an electrical signal to a gyro damping device and also to a servomotor which rotates the upper band clamp to untwist the band. North orientation is indicated when the null indicator is at rest on the meter zero position with no additional manipulation of the damping switch required.

h. The theodolite is mounted on a surface which is fixed to the upper band clamp; hence, it rotates with the upper band clamp when a signal is applied to the servomotor. The zero point of the theodolite horizontal scale is prealigned to the spin axis of the gyroscope, and upon completion of a damping operation, the zero

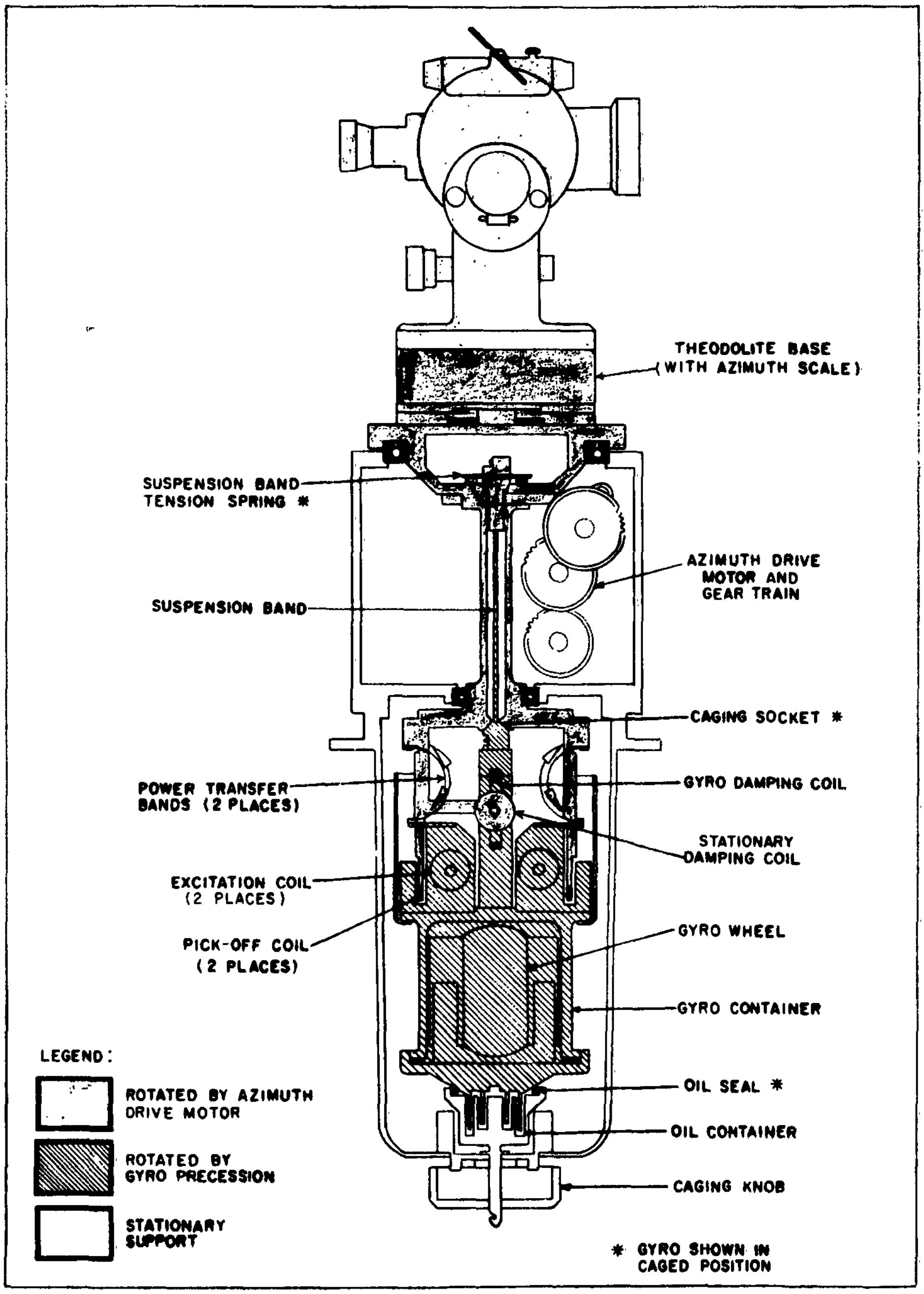

Fig. 2. Gyroscopic reference unit.

point of the scale is oriented to north and azimuth angles can be read directly from the theodolite scale.

5. Test Facilities and Tests.

a. Two first-order astronomic azimuths were used for control during the test: one at the Engineer Proving Ground, Fort Belvoir, Virginia, and the other at Fort Greely, Alaska. Secondary azimuths were established from these first-order azimuths to provide flexibility in test operations. The probable error of the secondary azimuths did not exceed 5 seconds of arc.

b. Facilities of the Climatic Test Section, U. S. Army Engineer Research and Development Laboratories, were used to determine the environmental characteristics of the instrument.

c. No additional laboratory equipment or test sites were required for the tests.

d. The various tests conducted, the purpose of the test, the method used, and the results obtained are shown in detail in Appendix C. Tests conducted were as follows:

(1) Physical Characteristics.

(2) Training Requirements.

(3) Ease of Operation and Safety.

(4) Performance and Accuracy.

(5) Wind Environment.

(6) Magnetic Environment.

(7) Temperature Environment.

(8) High Latitude Environment.

(9) Portability.

(10) Transportability.

(11) Maintenance.

(12) Electrical Power Requirements.

(13) Durability and Reliability.

(14) Adequacy of Equipment.

6. Summary of Tests.

a. The test instrument was, in general, satisfactory with respect to physical characteristics, training requirements, ease of operation and safety, magnetic environment, portability, electrical requirements, and maintenance.

b. Deficiencies were noted, however, with respect to low temperature operation, durability, performance and accuracy, transportability, and wind environment.

c. A list of deficiencies and suggested modifications is contained in Appendix D. An evaluation of the equipment with respect to Military Characteristics for Inertial Surveying Equipment Task is contained in Appendix E.

III. DISCUSSION

7. General. The Lightweight Gyro Azimuth Theodolite, Lear Model No. 11NG530A, was subjected to test by GIMRADA during the periods 19 thru 27 March, 2nd and 3rd of April, 11 thru 13 April, 26 April thru 6 May, 15 June thru 23 July, 2 thru 13 August, 12 thru 20 September, and 16 thru 19 October 1962. The intermittent nature of the test program resulted from equipment failures. Improvements were made during the periods that the equipment was returned to the contractor, but certain problems remained which could not be easily corrected in the present instrument design.

8. Test Approach. Accuracy and reliability were of prime concern during test of the instrument. While tests for these characteristics were being conducted under various conditions, other factors such as ease of operation, portability, etc. were also evaluated. The more severe tests, which might damage the instrument, were scheduled last. Observations were made with reference to known azimuths whenever possible; when a reference azimuth was not available during a test, calibration on a known azimuth line was done before and after the test. During certain tests, special precautions were taken to reduce the effects of known design deficiencies in order to evaluate the basic performance of the instrument.

9. Problems Encountered During Tests.

a. Gyroscope. During initial phases of testing, unsatisfactory performance due to improper gyroscope bearing preload was noted. This problem was ultimately corrected by developing a precise method of setting preload and affixing the bearings in place by the use of epoxy resin. The improved gyroscope ran during the remainder of the tests (over 400 hours) without additional problems from this source.

b. Caging. Accuracy tests after correction of the bearing preload problem indicated that the instrument performance was still not entirely satisfactory. Investigation revealed that the upper band clamp piston upon uncaging was seated randomly, causing azimuth errors. This problem was partially corrected by refinishing the seating surfaces. Subsequent accuracy tests indicated, however, that a residual azimuth error still occurred as a result of uncaging. The amount of error associated with this problem was found to be at least 0.10 mil (standard deviation). Subsequent accuracy tests were conducted with minimum caging during a series of azimuth determinations to minimize this source of error.

c. Leveling. It was observed during tests that the instrument was sensitive to level errors in both horizontal axes. Care was taken during each azimuth observation to insure that the instrument was level prior to reading the theodolite scale. The need for careful attention to level greatly affected the speed with which an observation could be made. The problem was further aggravated by the manufacturer's method of affixing the theodolite to the gyroscopic reference unit. The azimuth plate which supports the theodolite must be warped in order to achieve level of the theodolite with respect to the upper suspension point of the pendulous gyroscope. The azimuth plate was found to be unstable as a result of impinging solar radiation and possibly ambient temperature change. The result of this instability was that the theodolite level vial used in leveling the instrument became an unreliable indicator of the level condition of the upper band clamp causing loss of functional level of the pendulous gyro. Errors due to this could not be completely eliminated but were minimized by not exposing the instrument to direct solar radiation and by re-establishing functional level of the pendulous system when the accuracy data became erratic.

d. Calibration. The test instrument is calibrated by comparing gyroscopic azimuths with a known azimuth, then correcting any systematic error observed by rotating the horizontal scale of the theodolite. Maintaining proper calibration depends basically upon the theodolite circle remaining fixed. A horizontal scale clamp was not provided on the IKM-1 theodolite used with the instrument; hence errors could be introduced as a result of shock and vibration during handling. Movement of the circle was minimized during tests by careful handling and by sealing the circle setting knob of the theodolite. Calibration change specifically attributable to circle movement was not observed during test. It is known, however, that even with the circle motion knob sealed, as much as 0.8 mil of circle movement can exist under certain conditions. Other factors which result in apparent calibration changes are magnetic fields and suspension band creep. The latter effect was not observed during test, but a definite change in calibration resulting from magnetic fields was observed. This shift in calibration occurred as a result of an accidental rotation of the Mu metal shield surrounding the lower part of the gyroscopic reference unit. This shield appeared to accumulate a magnetic field or develop "hot spots" which interacted with the gyroscope. Reoccurrence of this problem was minimized by firmly affixing the shield in place and handling the instrument carefully during transport. The test instrument appeared to be insensitive to external magnetic fields.

10. <u>Accuracy</u>.

a. Accuracy tests performed under sheltered conditions during the initial phases of testing indicated an accuracy of 1.14 mils standard deviation. After correction of the gyroscope bearing problem and operating with minimum caging during tests, this error was reduced to 0.23 mil standard deviation or better. The error observed with caging after each azimuth determination was 0.32 mil standard deviation.

b. Unsheltered accuracy tests of the instrument conducted with shielding only from solar radiation yielded an accuracy of 0.38 mil standard deviation.

c. Accuracy tests under both sheltered and unsheltered conditions at latitude 64° north proved unsatisfactory, but repeatability tests in a controlled environment without caging after each observation showed a standard deviation of 0.37 mil.

11. <u>Environment</u>.

a. Wind was found to affect the operation and accuracy of the equipment by entering the gyroscopic reference unit through the azimuth bearing and over the top of the magnetic shield. This was improved by covering these areas as described in Appendix C, Test Number 5. Subsequent wind tests indicated that the instrument was capable of performing to 0.3 mil standard deviation in gusty winds up to 30 miles per hour.

b. Magnetic fields up to 6 gauss did not affect the operation or accuracy of the equipment. Other tests (see Appendix C, Test Number 6) involving magnets and large metal masses, were performed, but no effects on operation or accuracy were noted.

c. The test instrument performed satisfactorily from $+125^{\circ}$ F to 0° F; at -5° F, repeatability of azimuth determinations became erratic and remained unsatisfactory to -65° F. The unsatisfactory performance appeared to result from loss of gyroscope synchronism due to leakage of the hydrogen-helium atmosphere from the gyro container at -5° F.

12. Reliability.

a. The test instrument was operated for 462 hours during testing; during this period, a total of seven failures occurred.

b. For the last 300 hours of operation, one random failure occurred during low temperature operation; another failure actually occurred during this period, but this failure was caused by improper operation of the instrument.

13. Rejection of Data. The presence of problems of a developmental nature during the initial phases of testing required consideration of accuracy data in two groups in order to demonstrate the ultimate accuracy capability of the test instrument. The result of these early observations is given in this report in summary form only and is included in order to illustrate the magnitude of improvement afforded by the isolation and correction of these problems. Data accumulated after correction of these problems was used, without rejection of any of the observations, to compute the standard deviation obtained under the various test conditions.

IV. CONCLUSIONS

14. Conclusions. It is concluded that:

a. The Lightweight Gyro Azimuth Theodolite (Lear) meets the objective and Military Characteristics set forth in Task 1S6433-15D57811 for short range weapons orientation except as noted in Appendix E.

b. Upon correction of the deficiencies listed in Appendix D, the Lightweight Gyro Azimuth Theodolite (Lear) will be suitable for military field use.

APPENDICES

APPENDIX A

AUTHORITY

Item No. 2899
CETC Meeting #297

R&D SUB PROJECT CARD	TYPE OF REPORT: NEW		REPORT CONTROL SYMBOL: CSCRD-1 (R-1)
1. PROJECT TITLE: INERTIAL SURVEYING EQUIPMENT (U)		2. SECURITY OF PROJECT: UNCLASSIFIED	3. PROJECT NO.: 8-35-10-000
		4. INDEX NUMBER: 8-35-10-620	5. REPORT DATE: 22 August 1958
6. BASIC FIELD OR SUBJECT: Mapping, Charting and Geodesy	7. SUB FIELD OR SUBJECT SUB GROUP: Geodetic, Plane, and Hydrographic Surveying		7A. TECH. OBJ.: IO-13
8. COGNIZANT AGENCY: Corps of Engineers	12. CONTRACTOR AND/OR LABORATORY: US Army Engr Res & Dev Labs Fort Belvoir, Va.		CONTRACT/W. O. NO.:
9. DIRECTING AGENCY: Res. & Dev. Div., TO, OCE			
10. REQUESTING AGENCY: Office of the Chief of Engineers			
11. PARTICIPATION AND/OR COORDINATION: US Continental Army Command (C) Ordnance (C)	13. RELATED PROJECTS: 8-35-10-600		17. EST. COMPLETION DATES: RES.: ; DEV. Jan 59; TEST Aug 59; OP. EVAL. Jul 62
	14. DATE APPROVED: 3 October 1958 by GSUSA		
	15. PRIORITY: 1-A	16. MAJOR CATEGORY: 6.32	
19. REPLACED PROJECT CARD AND PROJECT STATUS:			

18. FY.	FISCAL ESTIMATES
59	25M
60	300M
61	100M
62	50M
T	475M

20. REQUIREMENT AND/OR JUSTIFICATION: Artillery and topographic mapping units require improved equipment and methods to provide accurate geodetic survey control with increased speed under all-weather, all-terrain and day-night operational conditions using jam-proof equipment having excellent security characteristics. These requirements, stemming from the advent of missiles and the speed and mobility of modern weapons exceed the capabilities of present methods and equipment. Requirements for this equipment are contained in paragraphs 439e(12) and 1512b of CDOG.

21. BRIEF OF PROJECT AND OBJECTIVE

a. Brief:

(1) Objective: To adapt currently available portable gyroscopes to military field use, with sufficient accuracy for artillery surveys; and to conduct the necessary studies to establish principles and techniques for the creation of new and improved methods and equipment for the full utilization of gyroscopic or other inertial principles in geodetic surveying by military units. The ultimate equipment may be a portable, continuously-indicating navigating system applicable to both ground and airborne vehicular operation, which would provide an all-weather, all-terrain, day-night, and jam-proof survey system having excellent security characteristics. The equipment should be capable of direct determination of azimuth with an accuracy suitable for artillery and topographic surveys and of providing

22. OASD (R & D)	SN.	CN.	C.	X.	I.	C.

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R&D SUBPROJECT CARD
CONTINUATION SHEET

Item No. 2899
CETC Mtg #297

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NO.
INERTIAL SURVEYING EQUIPMENT (U)	Unclassified	8-35-10-000
	4. 8-35-10-620	5. REPORT DATE 22 Aug 58

other survey data required in establishing ground positions. The primary and immediate objective is to test, modify, and/or develop the orienting device required as a component of the Artillery Survey System. The seconday and long range objective is the study, modification, and application of inertial equipment and methods for an ultimate inertial survey system to meet requirements of both Engineer and Artillery units.

(2) Military Characteristics: See Exhibit "A".

b. Approach:

(1) Significant advances are currently being made in the field of inertial systems for guidance of missiles and in navigation. Present state of the art indicates accuracy and portability of gyroscopic or other inertial systems are practical for consideration as survey instruments. The subproject objectives cited in 21a(1) will be accomplished in two phases.

(2) Phase No. 1: Commercial models of the more suitable domestic and/or foreign gyroscopic orienting devices will be selected for study and comparison. The most suitable item(s) will be modified as necessary for military use with primary emphasis on meeting requirements for the Artillery Survey System, Project No. 8-35-10-600.

(3) Phase No. 2: A study will be made of the problem in general and of work already accomplished in the field of inertial systems, both domestic and foreign. Application of inertial principles to surveying and geodesy will be fully explored in search of a more universal approach in obtaining survey data. Experiments may be required to prove the suitability of new principles and/or methods. Consideration will be given to the design of a comprehensive system of survey equipment utilizing these principles in providing rapid geodetic measurements of suitable accuracy for military surveys. The system will provide geodetic positions and other survey data on a continuous read-out form during vehicular transport with an accuracy at least adequate for low order field artillery surveys. This approach may lead to an ultimate independent system which would be organic in itself for obtaining all types of survey control data in one operation meeting requirements of both artillery and engineer survey units.

(4) Under Phase No. 1:

(a) Existing equipment will be modified, or experimental model(s) will be designed, built, and tested in the laboratory and in the field to determine operational accuracy and performance characteristics.

(b) Modification to the equipment to meet the established military characteristics will be made as required and additional tests conducted, if necessary.

R&D SUBPROJECT CARD
CONTINUATION SHEET

Item No. 2899
CETC Mtg #297

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NO.
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(c) Service tests will be recommended, if required, by principal using agencies.

(d) Drawings and specifications will be prepared upon completion of tests and necessary modifications.

(e) Recommendations will be submitted regarding classification of equipment, basis of issue, and existing production facilities.

(5) Under Phase No. 2: The study may reveal suitable types of equipment which could be adapted to the desired ultimate independent survey system. In such case, separate developmental project(s) would be initiated as required.

c. Other Information:

(1) Scientific Research: It is expected that one research study contract will be required under Phase No. 2.

(2) Reference: First Indorsement to Chief of Engineers, from Office, Chief of R&D, DA, 29 May 1958 to basic letter ATDEV-1, 400.114/11(C) (27 Mar 1958) from Headquarters, USCONARC to Chief of R&D, DA, subject: "USCONARC Approved MCs for Artillery Survey System (U)," which assigns overall development cognizance of the Artillery Survey System to the Chief of Engineers and requests expeditious development of the projects comprising the system under a 1-A priority.

(3) Interested Agencies: Agencies interested in this subproject, in addition to the Corps of Engineers, with which liaison will be maintained, and which will be furnished copies of reports on the subproject are: USCONARC, ABMA, USAF, USN (Marine Corps), Ordnance Corps, Signal Corps,

APPENDIX B

PHOTOGRAPHS

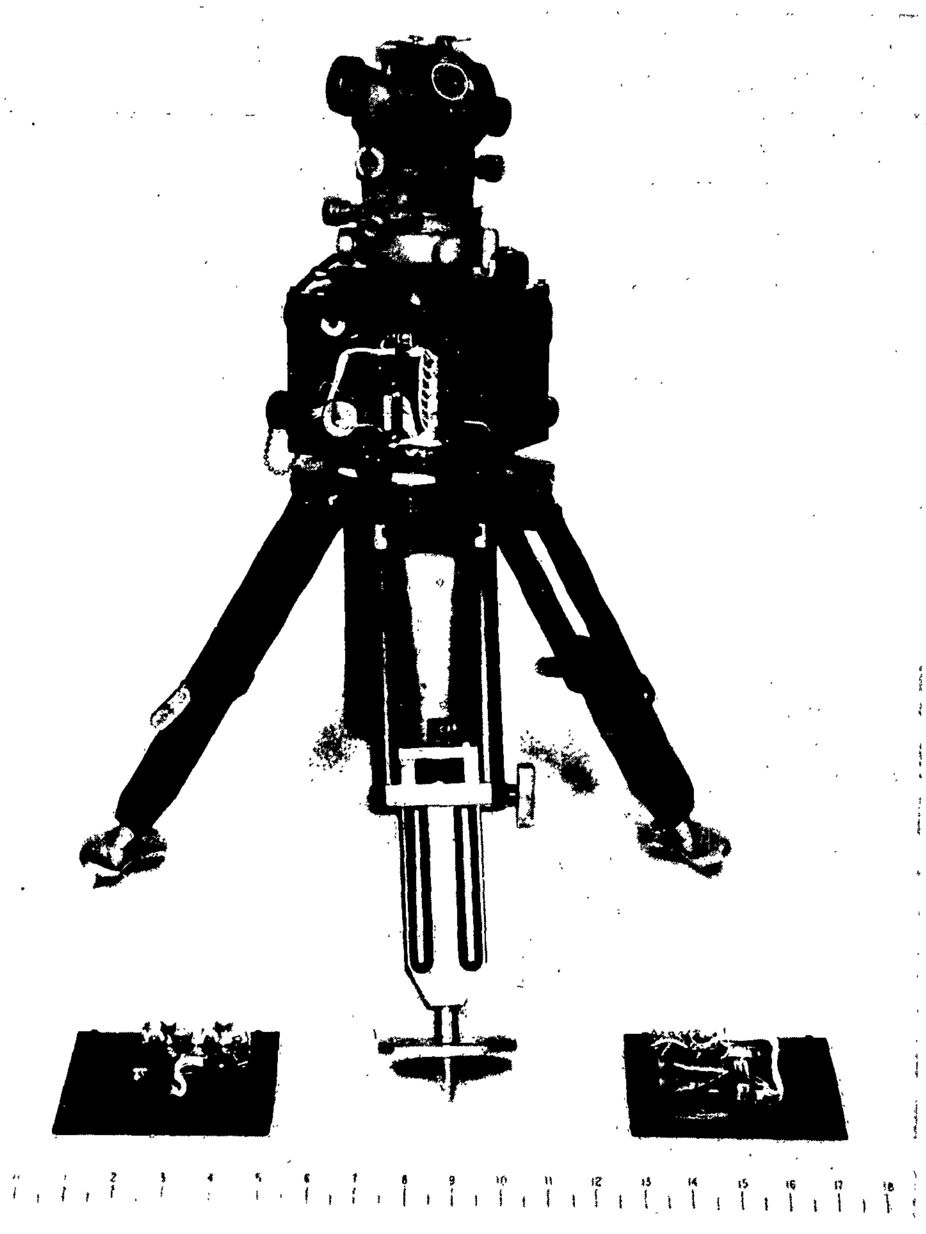

Fig. 3. Gyroscopic reference unit and tripod with attached Kern DKM-1 Theodolite. Two side panels are removed, showing attached electronic circuitry.

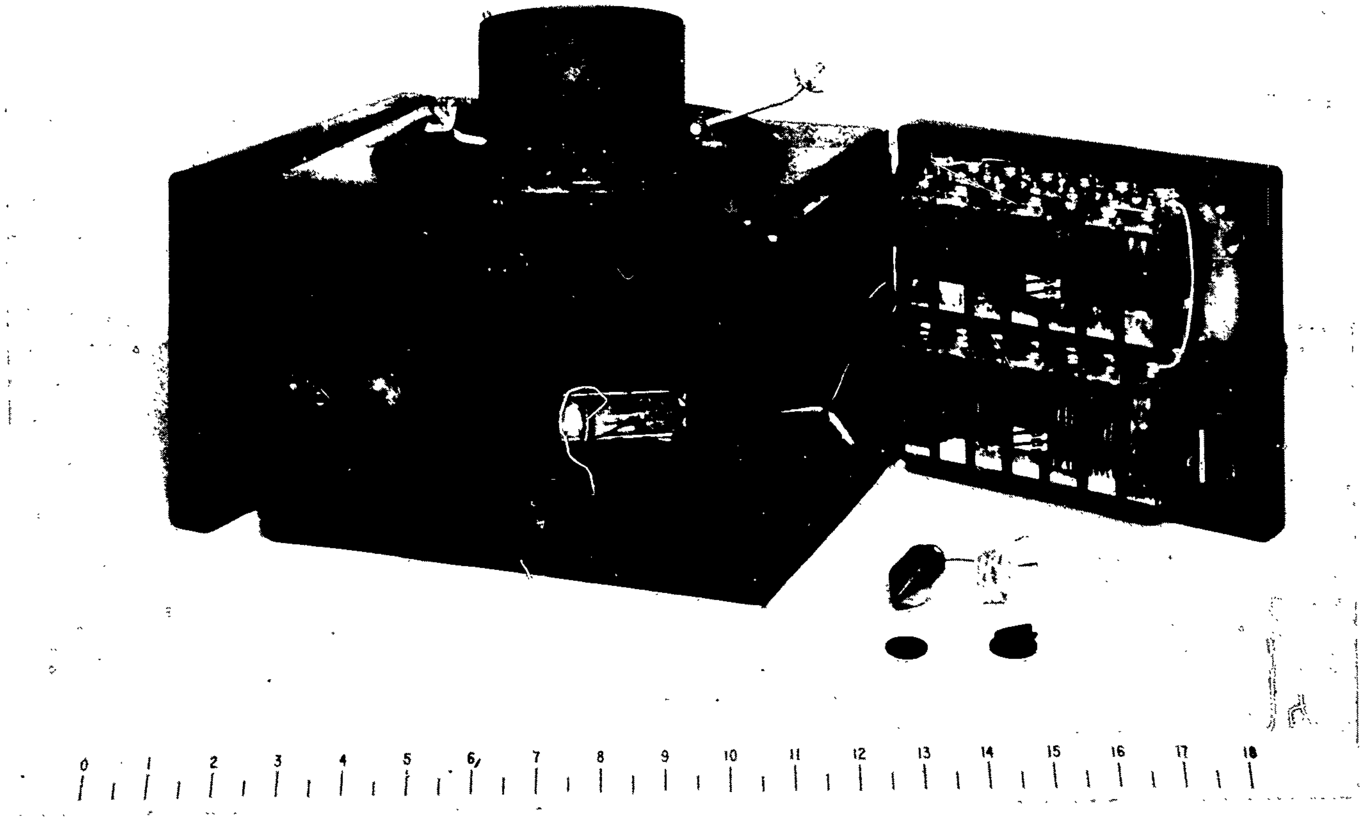

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Fig. 4. Opened electronic control unit showing 24-volt internal battery power supply. Plumb bob and theodolite eyepieces are shown.

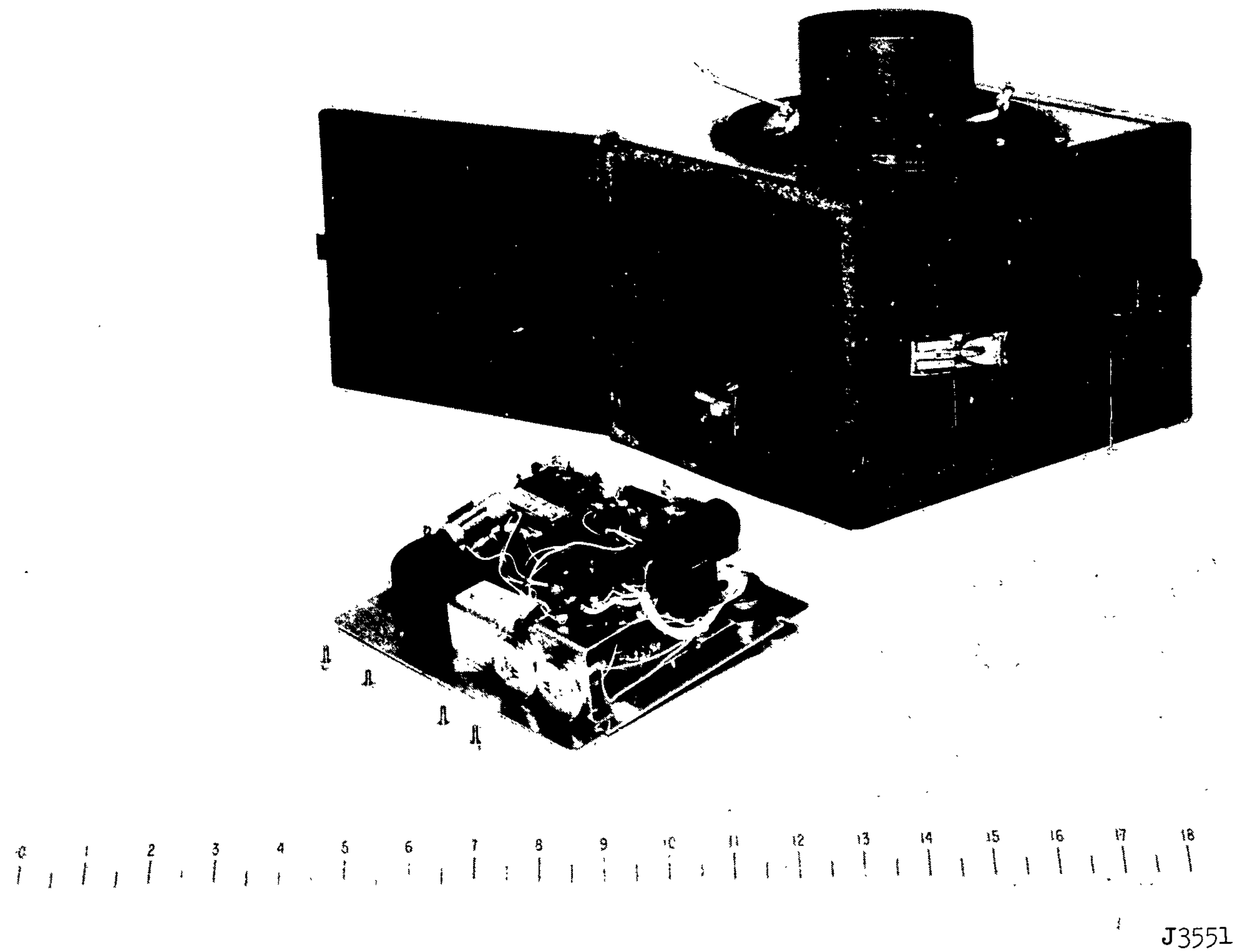

Fig. 5. Electronic control unit with control panel removed, showing the static inverter.

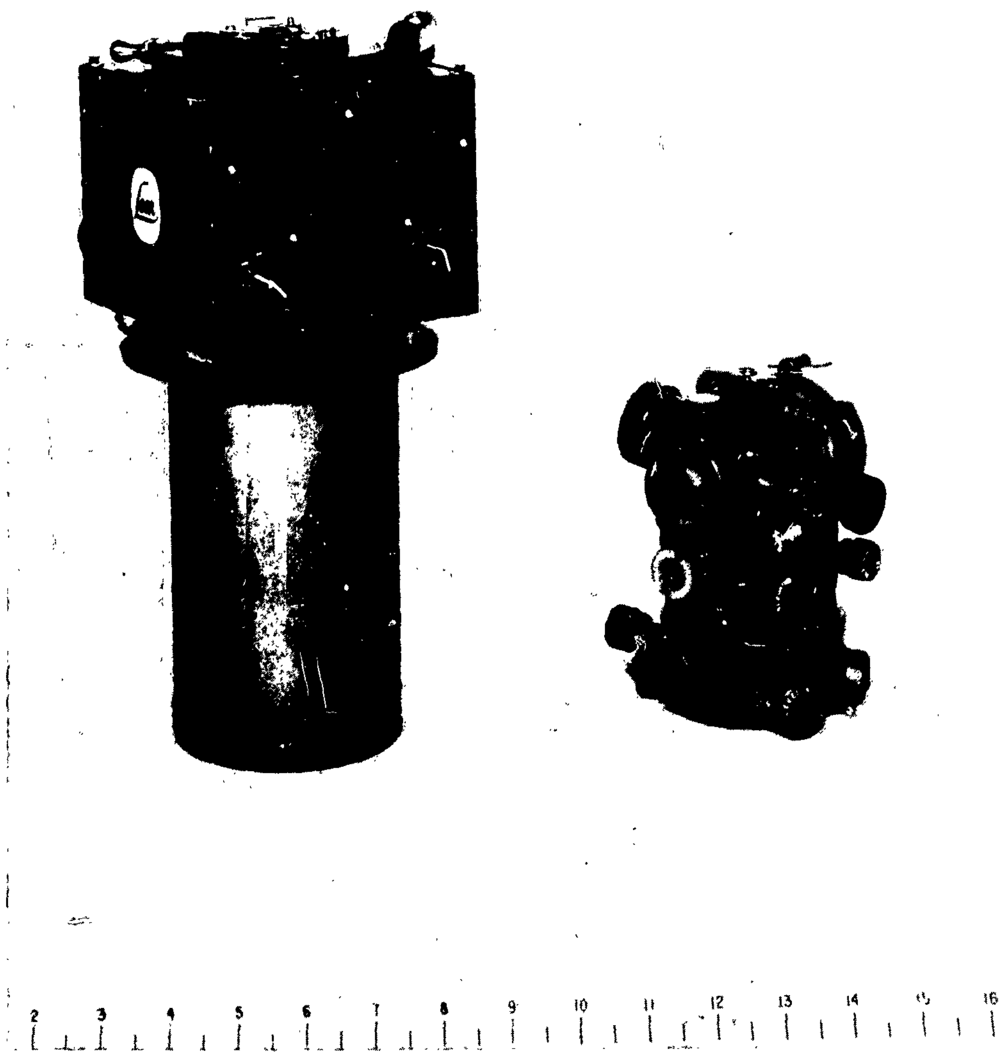

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Fig. 6. Gyroscopic reference unit with theodolite detached.

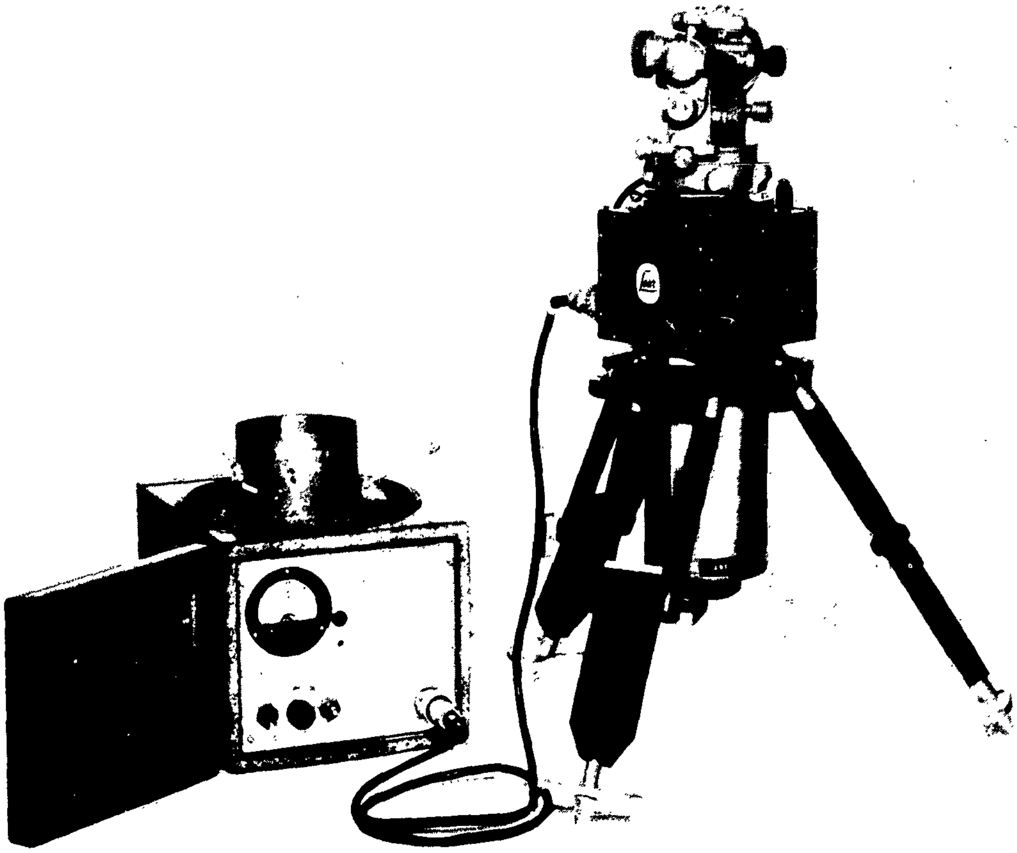

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Fig. 7. Electronic control unit, gyroscopic reference unit, and tripod assembled for operation.

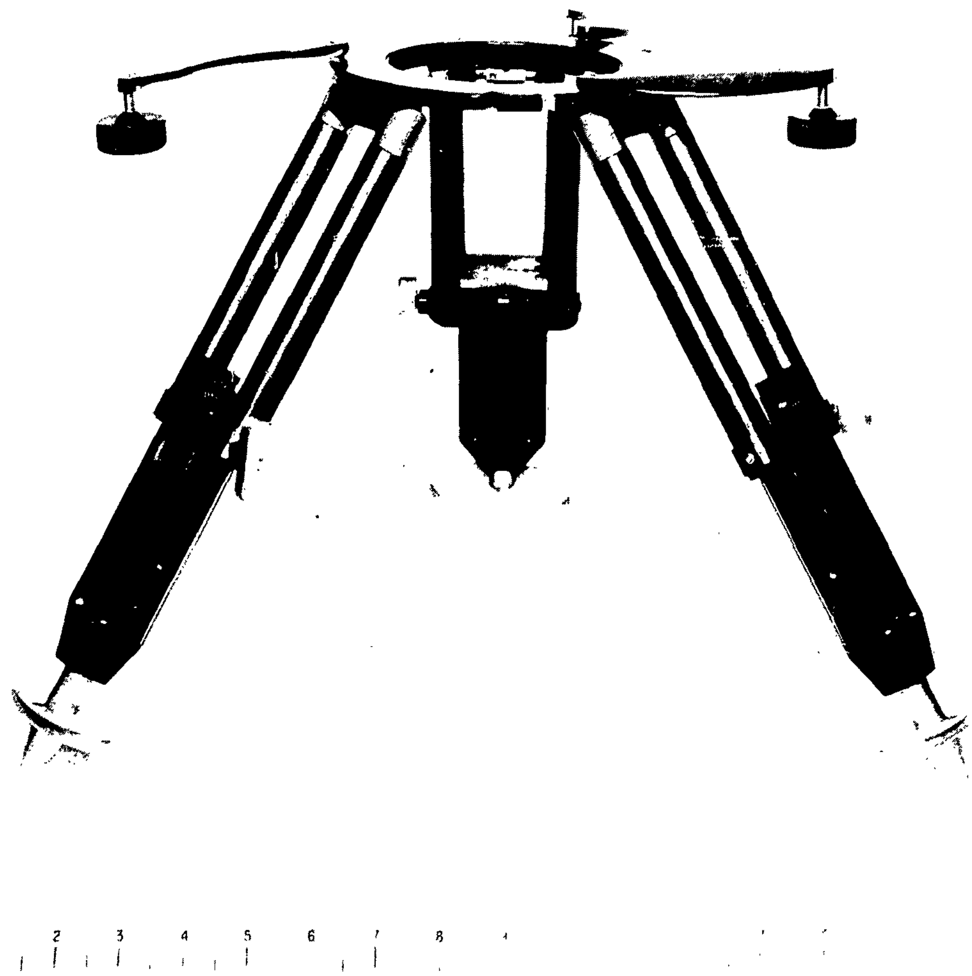

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Fig. 8. Tripod with gyroscopic reference unit mounting clamps opened.

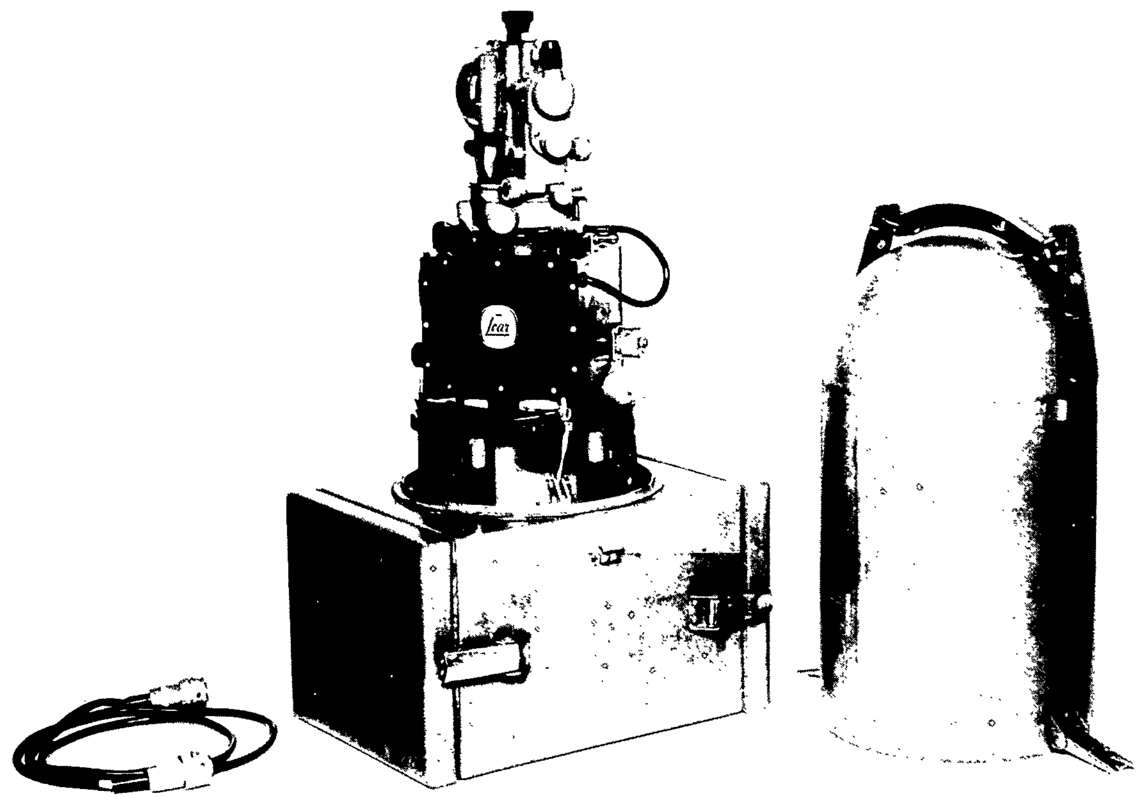

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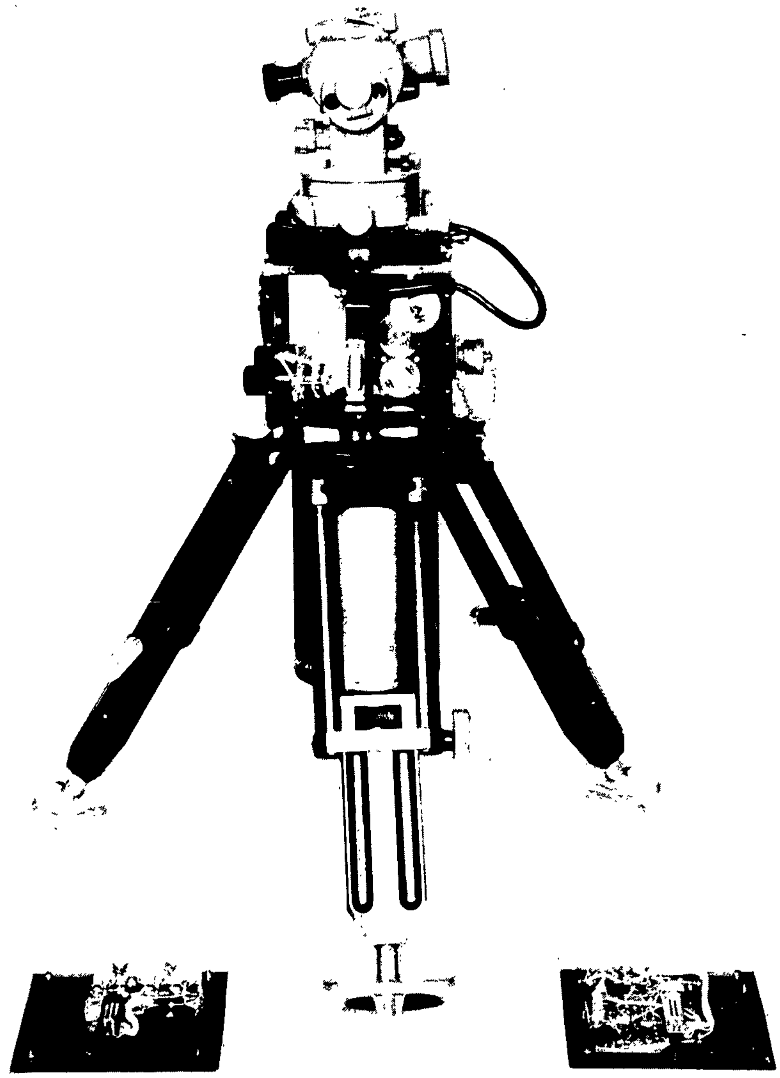
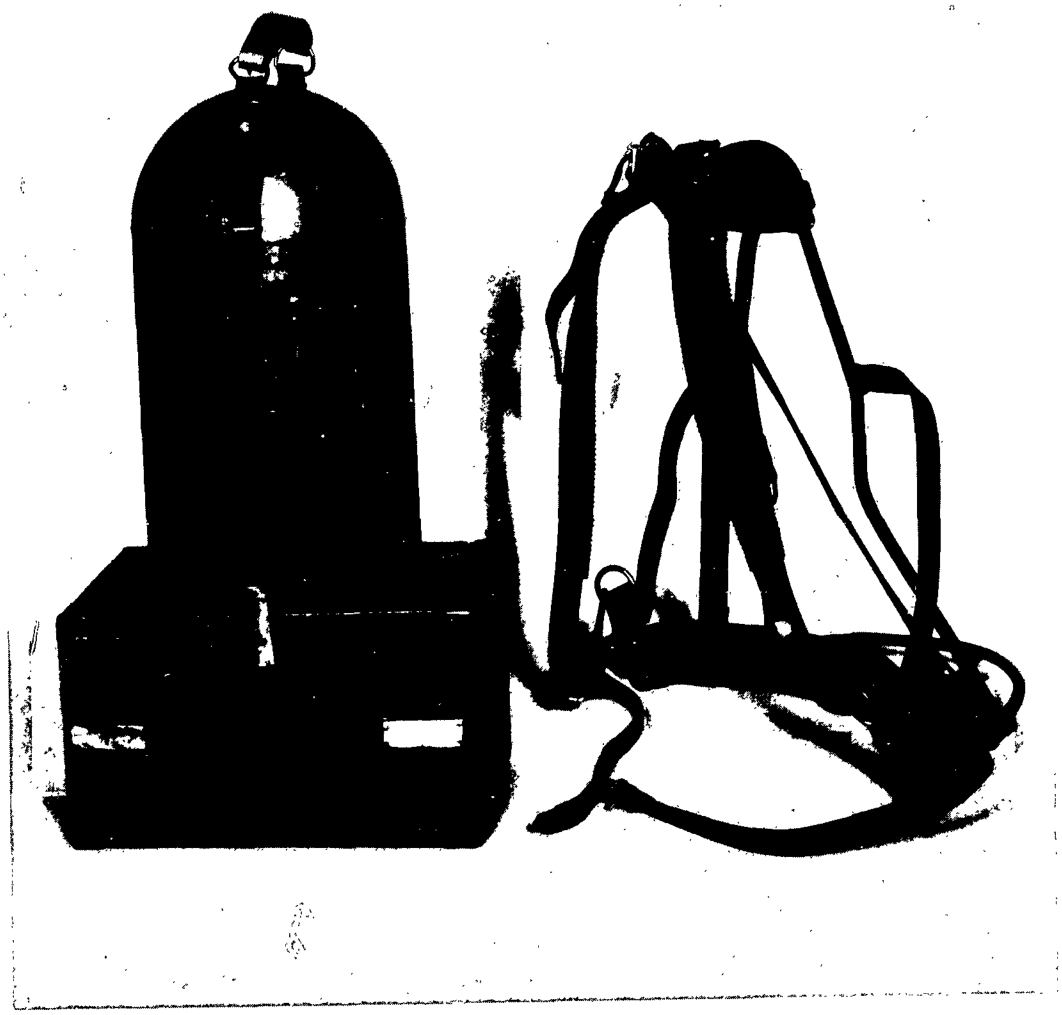
Fig. 9. Gyroscopic reference unit and tripod inserted in the electronic control unit which, with cover shown on right, acts as carrying case.



J3558
Fig. 10. Gyroscopic reference unit and tripod with attached theodolite. Two side panels are removed.



J4033

Fig. 11. Lightweight Gyro Azimuth Theodolite packaged for transportation. Backpack is shown.

J4035

Fig. 12. Lightweight Gyro Azimuth Theodolite being backpacked.

APPENDIX C

DETAILS OF TEST

PHYSICAL CHARACTERISTICS

TEST NUMBER 1

1. PURPOSE.

a. To determine the physical characteristics of the test instrument.

b. To insure that the test equipment is in proper condition for test operation.

2. METHOD.

a. The test equipment was weighed, measured, and photographed.

b. The test equipment was checked for proper assembly, completeness, and condition. Damages, defects, and determinable causes were recorded.

c. Adjustments made to equipment during assembly were recorded.

3. RESULTS.

a. The following tabulation lists the weights, dimensions, and volumes of the test instrument and accessories:

ITEM	WEIGHT	DIMENSIONS (in.)	VOLUME (cu ft)
Gyroscopic Reference Unit with Theodolite	13 lb 3 oz	17.5 x 3.8 x 3.8	0.14
Combined Carrying Case-Electronic Control Unit with Batteries	12 lb 10 oz	12 x 8 x 7	0.39
Tripod	5 lb 9 oz	Plate diameter 6.5 Legs 7.5 to 13	
Total System Packaged for Carrying	31 lb 6 oz	21.5 x 12 x 8	0.77

b. The test instrument upon delivery was complete, assembled properly, and showed no damage as a result of shipment.

c. No adjustments were necessary prior to operation.

d. Descriptive photographs appear in Appendix B.

TRAINING REQUIREMENTS

TEST NUMBER 2

1. PURPOSE.

To determine the training required to familiarize personnel with the operation of the equipment.

2. METHOD.

a. Selected personnel were given general operating instructions. A qualified operator conducted practical training.

b. The equipment was set up on lines of known azimuth, observations were made, and results were recorded.

c. Recording and computation of data were made on forms devised by test personnel.

d. The number of personnel needed to efficiently operate the instrument was noted.

e. The adequacy of and the need for additional instruction plates were noted.

3. RESULTS.

a. No instruction plates were provided. A warning plate relating to the need for caging the gyroscope prior to moving the instrument is required.

b. Transport, setup, and operation was found to be efficiently handled by one man.

c. Personnel previously trained in the operation of theodolites can be trained to operate the instrument in 4 hours.

d. GIMRADA Data Forms were used throughout the tests; a standard Field Notebook is more suitable for normal field operation.

EASE OF OPERATION AND SAFETY

TEST NUMBER 3

1. PURPOSE.

To determine the ease with which the test instrument can be operated and to determine the presence of safety hazards relative to field operation and maintenance.

2. METHOD.

a. The ease of operating the test instrument under field conditions was noted.

b. Potential safety hazards in routine operation and in field maintenance were noted.

c. The requirement for and adequacy of warning plates were noted.

3. RESULTS.

a. The gyroscopic reference unit housing had to be oriented to within 10 mils of north before accurate azimuth determinations could be made. The need for preorientation resulted from the effects of the internal magnetic fields associated with the gyroscopic reference unit. It was necessary to prealign these fields to the same approximate orientation with respect to north that existed at the time the instrument was originally calibrated in order to maintain accuracy within acceptable limits. This caused no difficulty when operating on a baseline known to within 10 mils, but when determining an unknown azimuth, one or two preorientation determinations had to be made before the housing could be positioned well enough to determine accurate azimuths. Each preorientation determination required about 15 minutes, increasing the total operation time by 15 to 30 minutes.

b. The tripod leveling screws were too coarsely threaded for efficient leveling to the precision required.

c. No safety hazards were noted. No warning plates are considered necessary.

d. During testing, the instrument was operated by more than 12 personnel. None had any difficulty in learning to operate the instrument.

e. Removing and replacing the instrument in the carrying case was found to be difficult due to the small clearances for the tripod legs. In addition, the inverter is exposed and subject to damage by the legs.

f. The internal batteries are easily rechargeable.

PERFORMANCE AND ACCURACY

TEST NUMBER 4

1. PURPOSE.

To determine the performance and accuracy characteristics of the test instrument under sheltered and unsheltered conditions and the time required to perform azimuth observations under normal field conditions.

2. METHOD.

a. With the instrument sheltered from sun and wind, 83 azimuth determinations were made from a tent on the roof of the observatory at the Engineer Proving Ground, Fort Belvoir, Virginia. Two known azimuth references, 500 yards and 2 miles distant, were used for control. The instrument was caged between each azimuth determination. The 83 observations were taken over a period of 2 days during which the instrument was moved from its operating position only once.

b. One hundred twenty-three sheltered observations were made from the observatory garage to a known azimuth marker about 200 meters distant. The gyro was uncaged only as necessary, averaging about once every 7 azimuth determinations. Fifty-five observations were taken later under similar conditions with a slightly different calibration value for the instrument. The 123 observations covered a period of 8 days. The 55 observations covered a period of 5 days. During each period, the instrument was not moved from its operating position on the floor of the observatory garage.

c. With the instrument unprotected from wind or rain but protected from direct sunlight, repeated azimuth determinations were made to known azimuth references. Three different field locations at the Engineer Proving Ground were used. A second unit was also tested in this manner.

3. RESULTS.

a. Sheltered Tests.

(1) The results of the sheltered tests are shown in Figs. 13 and 14. The standard deviation of the 83 azimuth determinations taken with caging between each observation (Fig. 13) is 0.30 mil of arc. The standard deviation of the two groups of observations taken

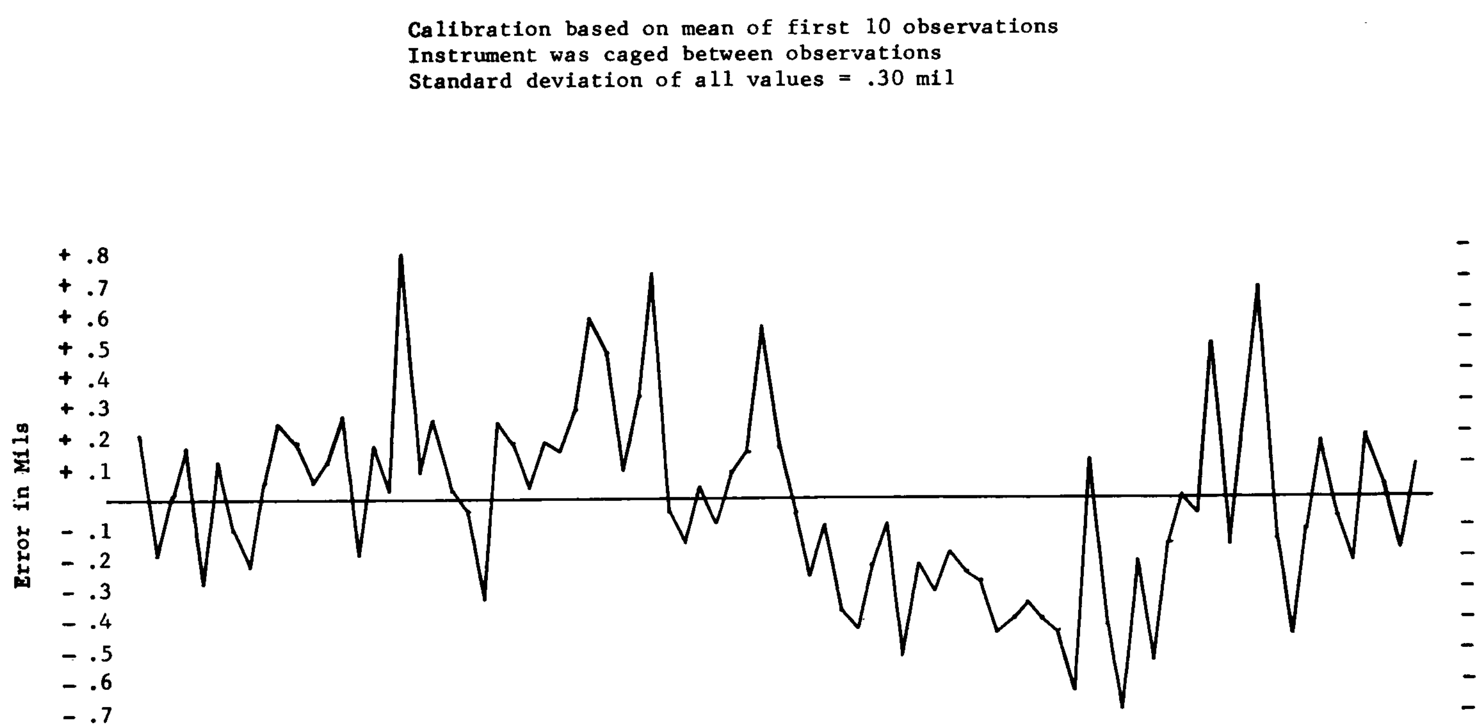


Fig. 13. Sheltered accuracy test results.

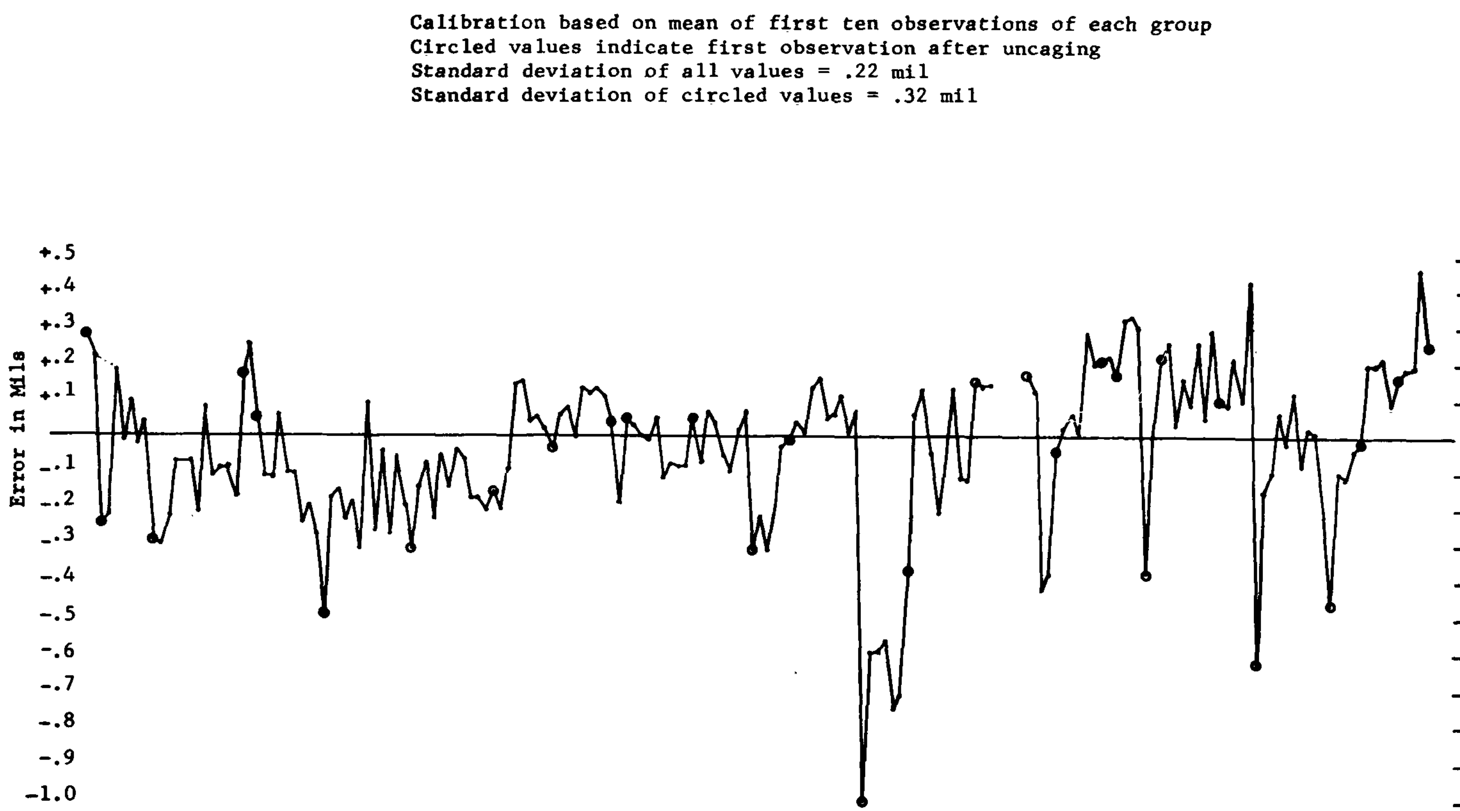


Fig. 14. Sheltered accuracy test results.

with minimum caging (Fig. 14) is 0.22 mil. Taken separately, the two groups of 123 and 55 observations each show about the same accuracy, 0.22 and 0.23 mil, respectively.

(2) The first 10 observations of each of the three groups were used to calibrate the instrument. This number seems to be adequate since the standard deviation of each group based on its mean value is in each case no more than 0.02 mil less than the standard deviation based on the mean of the first 10 observations.

(3) During the time between the two groups of observations shown in Fig. 14, the outer magnetic shield was inadvertently rotated a slight amount, causing a large (1.7 mils) calibration change. The shield was reorientated as close as possible to its original position, but a small shift (0.3 mil) in subsequent observations was noted. The instrument was therefore recalibrated by using the first 10 observations.

(4) The first azimuth determination made after the instrument has been caged is about 0.10 mil less accurate than subsequent determinations. This is shown by a comparison of the results shown in Figs. 13 and 14. In Fig. 14, the circled values show when the gyro was uncaged. During this part of the test, when the gyro was not caged, it was rotated off null between observations. The standard deviation of those observations taken immediately after uncaging (the circled values) is 0.32 mil. This compares well with the 0.30 mil standard deviation of the results shown in Fig. 13, which were taken with caging between every observation. These two accuracy figures, 0.32 and 0.30 mil, compared with the 0.22 mil standard deviation for the results obtained with minimum caging, show the effect of caging on the accuracy of the instrument.

(5) Observation time averaged 20 minutes. This includes observations taken by relatively inexperienced operators.

b. Unsheltered Tests.

(1) The first attempts to determine the accuracy of the equipment under unsheltered conditions showed irregular results due to wind entering the instrument (see Test Number 5). With a makeshift "wind collar" added to the instrument, the equipment was again operated under unsheltered conditions for 3 days. The results obtained from two field locations (see Fig. 15) show good repeatability for any one day but poor accuracy compared to the known azimuths. Gusts of wind up to 25 miles per hour and several hours of light rain were encountered, but neither showed any effects on operation or accuracy. The 1- and 1.5-mil shifts between days and locations

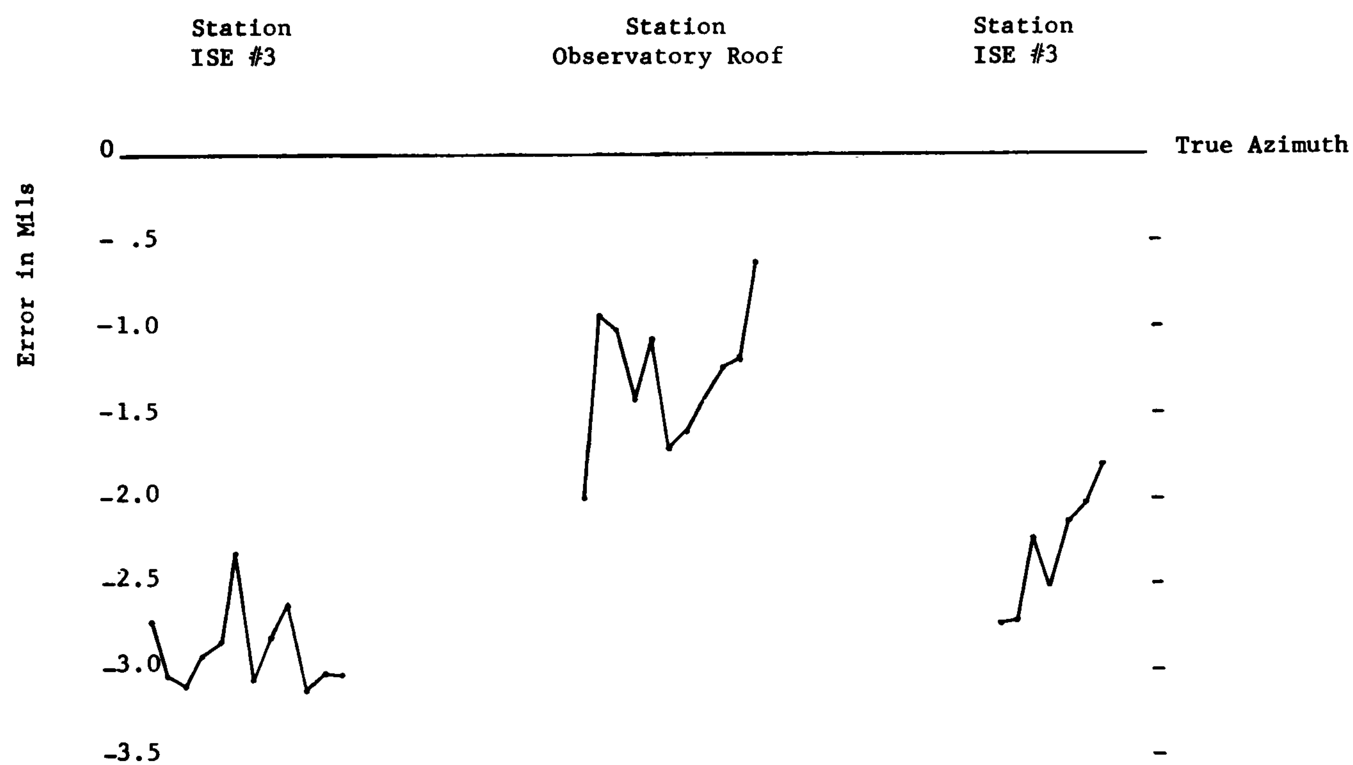


Fig. 15. Unsheltered accuracy test results, Lear Lightweight Gyro Azimuth Theodolite Unit #1. Instrument was caged only between stations.

may have been due to caging, functional level, or calibration changes. Disregarding these shifts, the standard deviation of the results was 0.33 mil. This is, of course, based on repeatability; the "calibration error" of each day's results being ignored.

(2) On 11 October 1962, a second unit essentially identical to the equipment being tested was received from Lear Siegler, Inc. The calibration and accuracy of this second instrument was checked for 1 day under sheltered conditions and found to be satisfactory. Unsheltered accuracy tests were then rerun as shown in Fig. 16. The considerably improved results indicate that the first unit could have been out of adjustment during the unsheltered accuracy tests. In any case, the results obtained by the second unit show the accuracy that is possible with this type of instrument under unsheltered conditions. The standard deviation of the unsheltered test results of the second unit, based on the calibration obtained previously, is 0.38 mil. With this unit, the repeatability at each particular station was again found to be better than the overall results. The standard deviation of the results based on repeatability and discounting the shifts between stations is 0.22 mil. The exact cause of the shifts between stations was not determined, but it is known that transportation can cause functional level and calibration changes and that caging introduces errors; either of these could contribute to the observed shifts.

(3) The time required to determine the azimuth varied considerably, depending on whether releveling was required during the observation. The instrument could be nulled in 15 minutes, but if releveling was required, an observation could take from 20 to 40 minutes. Considerable releveling was required during the unsheltered tests, and observation time averaged 25 minutes. It was discovered during the test that when the gyro was rotated off null, the actual level of the instrument, as measured by the level vial, was changed due to imperfections in the alignment of the theodolite base plate and the upper band clamp bearings. As the theodolite was rotated back towards null, the level would return unless the instrument had been releveled while away from null, in which case releveling was again required.

c. To achieve the accuracies obtained during these tests, it was necessary to preorient the gyroscopic reference unit housing to within 5 to 10 mils of north. When operating on a known baseline, this is easily accomplished; but when azimuth is not known, the preorientation of the equipment may require from 15 to 30 minutes. Thus the total time required for the first field observation at a station including setup, plumbing, preorientation, final nulling, and readout, varied from 40 minutes to 1 hour.

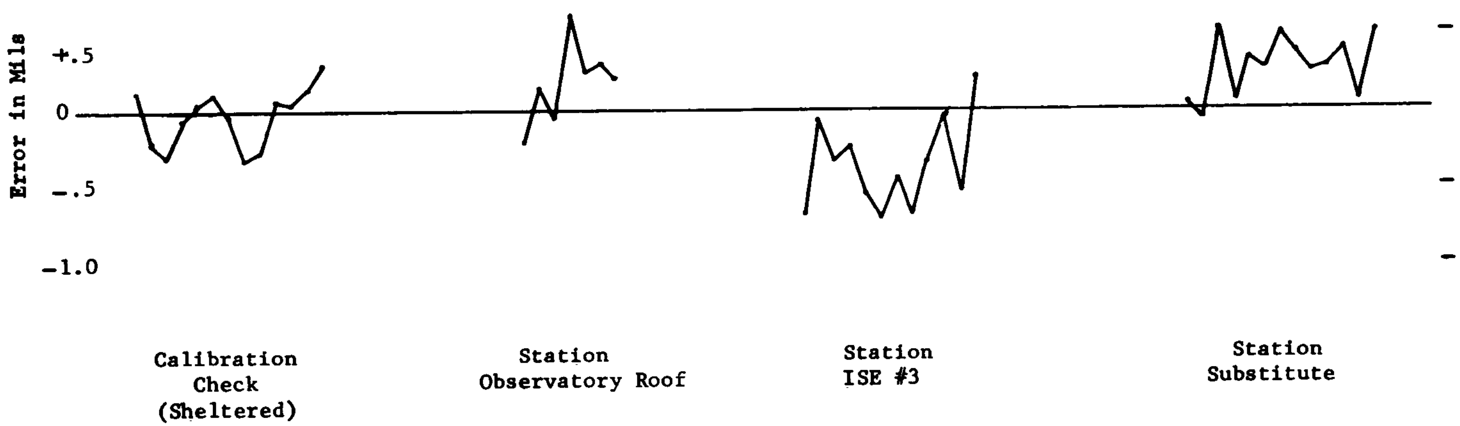


Fig. 16. Unsheltered accuracy test results, Lear Lightweight Gyro Azimuth Theodolite Unit #2. Instrument was caged only between stations.

WIND ENVIRONMENT

TEST NUMBER 5

1. PURPOSE.

To determine the effect of winds on the operation and accuracy of the test instrument.

2. METHOD.

The test instrument was operated without shelter in the presence of simulated winds of 15, 20, 25, and 30 miles per hour. The site selected for the test provided a controlled environment in terms of disturbing influences from natural wind, solar radiation, and seismic vibrations which might confuse test results. A two-speed blower having a wind area of sufficient size to cover the test instrument was used to simulate winds of various speeds. The desired wind speeds were obtained by varying the motor RPM control on the blower and also the distance of the blower from the test instrument. A precise anemometer was used to control the distance of the blower from the instrument. The simulated wind was directed at the test instrument in a horizontal plane both parallel and perpendicular to the spin axis of the gyroscope at each wind speed. Gusty wind was simulated by periodically interrupting the air stream from the blower. The effect of wind on instrument performance was noted by leaving the instrument uncaged and at null while applying or changing the wind speed. If the null indicator moved, the gyro was redamped and a new azimuth value determined.

3. RESULTS.

a. Initially it was apparent that the test instrument was sensitive to wind. Large oscillations of the null indicator were noted, and azimuth observations varied by 0.70 mil from the reference azimuth.

b. Investigation indicated that wind was entering the gyroscopic reference unit through the azimuth bearing and an open space at the top of the magnetic shield. Temporary corrective measures were made by blocking these openings with tape, and tests were continued.

c. Tests conducted after application of these corrections indicated that the test instrument could be operated in gusty winds up to 30 miles per hour from any direction to an accuracy of about 0.3 mil standard deviation.

d. Gusty winds of 30 miles per hour caused oscillation of the null indicator about the zero position of the meter scale. This oscillation did not interfere with normal operation of the instrument except to require a minor increase in observing time.

e. Maintaining instrument level also proved to be slightly more difficult in the presence of the gusty wind; this again only affected the observing time.

MAGNETIC ENVIRONMENT

TEST NUMBER 6

1. PURPOSE.

Tests were conducted to determine the effects of magnetic fields upon instrument accuracy.

2. METHOD.

a. A Helmholtz coil was modified to permit placing the test instrument in the center of the field generated by the coils. The device was calibrated by means of a gauss meter with the tripod of the test instrument in the test position.

b. With the modified Helmholtz coils, magnetic fields were established in the north-south, east-west, southwest-northeast, and vertical directions. For each direction, current through the coils was changed in order to provide field strengths from 0.5 gauss to 3 gauss and, in some cases, up to 6.8 gauss. At maximum flux densities, the current was reversed to provide a field in the reverse direction.

c. For each orientation of the coils, the instrument was nulled, the current was then turned on, and the instrument null meter was observed to see if the magnetic field caused a deflection. The null was observed for 4 to 6 minutes; the current to the coils was then shut off. The null meter was again observed for 4 minutes to see if loss of field caused any change.

d. In addition to the tests mentioned above, three nonquantitative tests were carried out. In each of these tests, the instrument was nulled and observed for at least 2 minutes after a field change.

(1) A small horseshoe magnet of unknown gauss rating was placed approximately an eighth of an inch from the gyroscopic reference unit at various critical points. The gap between the poles of the magnet was small, thus limiting the field dispersion.

(2) A large ferrous metal object was placed less than 1 inch from the gyroscopic reference unit.

(3) An automobile was driven to within 1 inch of the gyro sensor unit and parked in a south-west direction. After the

null meter was observed, the automobile was moved to a south-east orientation.

3. RESULTS.

a. The test using the modified Helmholtz coil indicated no effect on instrument accuracy with:

(1) North-south field orientation with field strengths from 0.5 to 3.3 gauss.

(2) East-west field orientation with field strengths from 0.5 to 5.4 gauss.

(3) Southwest-northeast field orientation with field strengths of 3.3 and 5.5 gauss.

(4) Vertical field orientation with field strengths of 1.2 to 6.8 gauss.

b. No effects on accuracy were noted by the nonquantitative tests performed.

TEMPERATURE ENVIRONMENT

TEST NUMBER 7

1. PURPOSE.

To determine the effects of temperature on operation and accuracy of the test instrument.

2. METHOD.

a. The instrument was placed in the Portable Equipment Test Chamber of the Environmental Evaluation Branch, Fort Belvoir. Two Wild T-2 theodolites with illuminated reticles were placed on tripods and used as reference targets. One was placed inside the test chamber and the other was positioned outside directly opposite a window in the chamber. The test instrument was mounted on a standard tripod by means of a special adapter plate in order to provide the same viewing height as the two reference theodolites. The theodolite inside the chamber was subsequently found to be affected by the chamber blower and was not used as a reference during the test.

b. The test instrument was operated in the normal manner at various temperature levels starting at 70° F. From 70° F, the temperature was increased by 15° increments to 125° F. Returning to 70° F, the temperature was then lowered by 15° steps to -50° F. At each level, from two to six azimuth determinations were made. The gyro was not caged between observations at the various temperature levels. During most of the temperature changes, the gyro was also left uncaged and running for the time required to stabilize the instrument at the new temperature. When not caged, the gyro was rotated off null before making an azimuth observation.

c. The equipment was also stored for 4 hours at 155° F and 3 days at -65° F. No azimuth observations were made at these temperatures.

d. At a later date, the equipment was tested at room temperature and advanced directly to 125° F where simulated solar radiation at the rate of 360 BTU's per square foot per hour was applied to the electronic control unit. Observations were made in the same general setup as before except that the reference theodolite inside the chamber was stabilized and used as a check on the outside reference theodolite.

e. The ease of operating the instrument with heavy gloves was noted.

3. RESULTS.

a. Figure 17 shows the accuracy of the test instrument at the various temperature levels. The zero error baseline was established by averaging seven azimuth observations taken at 70° F before and after the high temperature test. The 1-mil difference between these two sets of readings is attributed to the test setup. Maximum instrument accuracies were not expected in the chamber. The metal floor and the several panes of window glass through which the outside reference theodolite had to be sighted could not be checked for movement and were believed to be affected by the temperature changes.

b. As shown in Fig. 17, accuracies as good as could be expected under the operating conditions were obtained above the -5° F temperature level. At -5° F, accuracy decreased markedly, both in regard to the reference azimuth and in repeatability. These degradations in accuracy continued to a greater or lesser degree throughout the rest of the low temperature testing. When the test item was returned to 70° F, repeatability was still poor and azimuth errors, though somewhat improved, averaged about 4 mils. It was later determined by the manufacturer that a leak had developed in the gyro container, resulting in loss of the hydrogen-helium atmosphere within the container. The gyro wheel normally runs in a hydrogen-helium atmosphere to reduce air drag; the presence of air in the gyro container causes excessive drag and prevents the gyro wheel from achieving synchronous speed. The loss of accuracy at -5° F and below appears to have been caused by this leak in the gyro container seal.

c. The test equipment operated normally at all temperature levels with the following exceptions:

(1) The azimuth servo responded in a more sluggish manner than normal at 10° F and below.

(2) At 40° F, a slight stiffening of the leveling screws was noted; no increase in stiffness was noted at lower temperatures.

(3) The vertical motion of the theodolite telescope stiffened slightly at both 125° F and 40° F. This stiffening became worse below 40° F, but the telescope could still be moved at -50° F.

(4) The horizontal motion of the IKM-1 started stiffening at 25° F. At -35° F, the motion became too stiff to reverse the telescope; however, small movements could still be made with the tangent screw. (Subsequent testing of IKM-1 theodolites has shown that these stiffening problems can be easily solved by proper lubricants.)

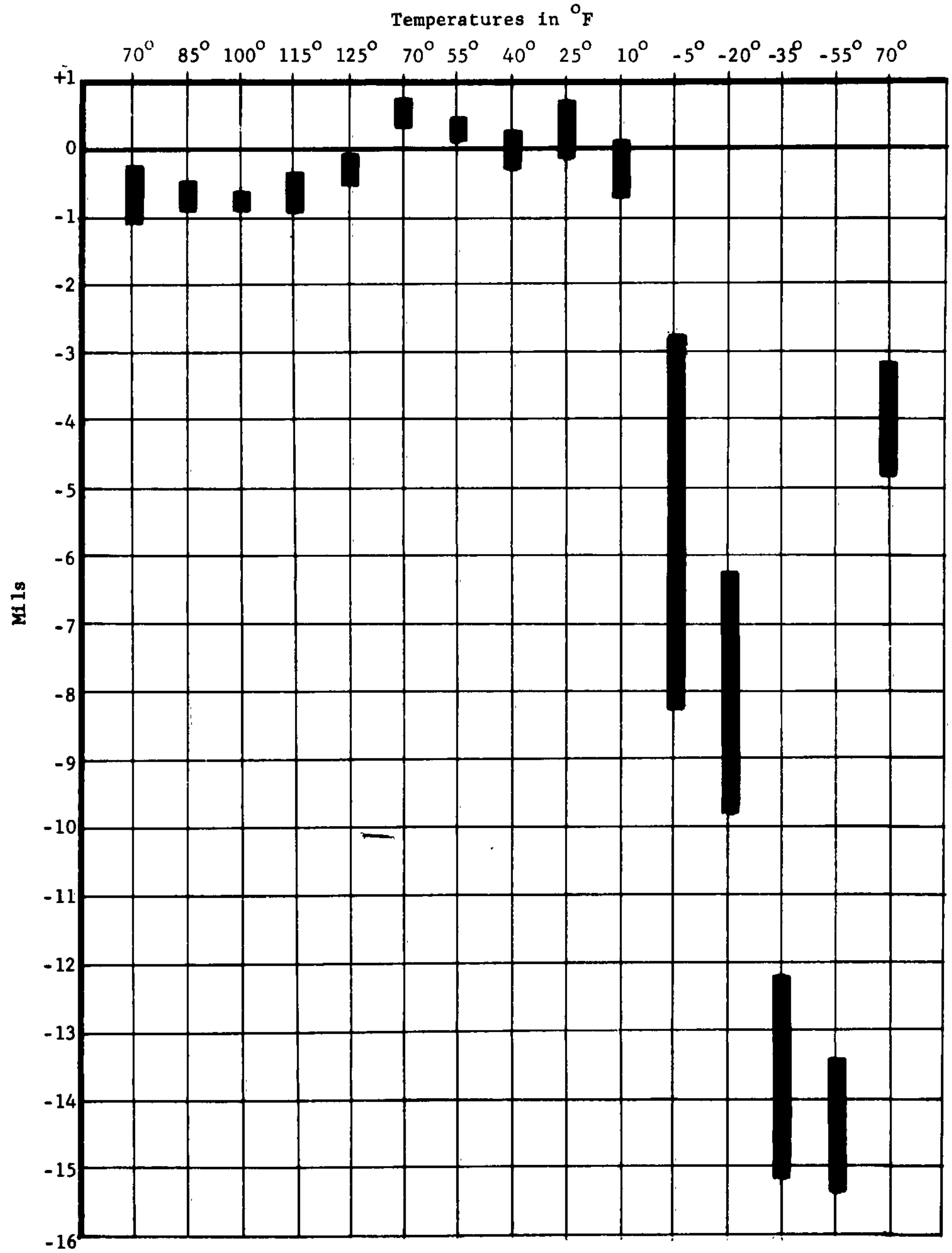


Fig. 17. Temperature Environmental Test. Bar indicates spread of reading at the various temperature levels.

d. The test at 125° F with solar radiation on the electronics package showed no abnormal effects on the operation of the test equipment. The azimuth observations at 125° F showed good repeatability but differed from those taken at 70° F by about 3 mils. This shift is attributed to the effects of ambient heat on the device causing a change in functional level of the instrument. Although this change did not occur during the previous test at 125° F (see Fig. 17), there were no other indications that the simulated solar radiation impaired the performance of the test item in any manner.

e. No external heating was applied to the test equipment during the low temperature testing. The operating capabilities of the test item indicate that very little modification is required to achieve satisfactory cold temperature operation. All control knobs except those on the DKM-1 theodolite could be operated with gloves on.

HIGH LATITUDE ENVIRONMENT

TEST NUMBER 8

1. PURPOSE.

To determine the performance characteristics of the equipment at high latitudes.

2. METHOD.

a. The equipment was operated at a latitude of 64° at Fort Greely, Alaska. Field observations were made under both sheltered (in a tent) and unsheltered conditions; the instrument was caged after each observation. The first-order azimuths were used for control.

b. Azimuth determinations without caging were also made under controlled conditions. Performance was evaluated by instrument repeatability.

3. RESULTS.

a. Field tests were discontinued because the instrument could not be made to perform with sufficient accuracy. Errors of over 3 mils unsheltered and over 1 mil sheltered were encountered. Subsequent testing (see Test Number 5) indicated that wind may have contributed some of the error observed during the unsheltered testing.

b. A series of 25 azimuth determinations under controlled conditions gave a standard deviation of 0.37 mil of arc, based on repeatability.

c. At 64° latitude, observation time increased 10 minutes.

PORTABILITY

TEST NUMBER 9

1. PURPOSE.

To determine the ease with which personnel can assemble and carry the test instrument as required for normal field operation.

2. METHOD.

The instrument was assembled in the carrying case, carried to the operating site, and prepared for operation.

3. RESULTS.

a. Assembly of the instrument in the carrying case can be accomplished by one man, but the arrangement is rather clumsy due to the close tolerances for the tripod footpiece.

b. When assembled in the carrying case, the equipment can be easily lifted and comfortably carried by one man.

c. The equipment can be prepared for operation by one man.

TRANSPORTABILITY

TEST NUMBER 10

1. PURPOSE.

To estimate the feasibility of transporting the test item in ground vehicles by determining the relative ease with which calibration changes due to theodolite circle movements can be made.

2. METHOD.

The instrument was set up and aligned on a target in the normal manner, except that the azimuth clamp was tightened more than is normal for field operation. The azimuth circle reading was then recorded. The theodolite leveling screws and frame were then tapped in various places and directions with a small wooden mallet. The theodolite was tapped with sufficient force to move the cross hairs off the target. After each movement, the divergence from the target was corrected by the azimuth tangent screw and the azimuth reading was recorded.

3. RESULTS.

Azimuth changes due to circle movement were obtained only when the theodolite was tapped below the alidade bearing. A maximum of 0.8 mil change was obtained when the leveling screw knobs were tapped with sufficient force to change pointings. No azimuth circle movements occurred when the alidade itself was tapped.

MAINTENANCE

TEST NUMBER 11

1. PURPOSE.

To determine the maintainability of the test equipment.

2. METHOD.

Maintenance required during the test program was noted.

3. RESULTS.

a. Maintenance instructions in the furnished manual are inadequate.

b. The various breakdowns which occurred during testing were repaired by Lear, Inc., personnel and usually required the return of the equipment to Lear, Inc.

c. Internal battery charging procedures were satisfactory and were performed during the test.

d. The equipment is not fused.

e. The readout light bulb for the theodolite was replaced several times with no difficulty.

ELECTRICAL POWER REQUIREMENTS

TEST NUMBER 12

1. PURPOSE.

To determine the electrical power requirements of the test equipment.

2. METHOD.

The instrument was operated from an external 24-V DC battery. Current was measured at the battery during operation.

3. RESULTS.

Power required to bring the gyro up to synchronous speed was 36 watts. Power required to maintain synchronous speed was 20 watts. Operation of the azimuth servomotor increased this to 22 watts.

DURABILITY AND RELIABILITY

TEST NUMBER 13

1. PURPOSE.

To determine the durability and reliability of the test instrument.

2. METHOD.

a. The test instrument was operated for 462 hours on 70 different days. One thousand sixty-three azimuth determinations were made.

b. The equipment was set up and taken down 58 times.

c. Excessive wear or failure of the test equipment as a result of handling, transport, or operation was recorded.

3. RESULTS.

a. The gyroscope failed four times. Three failures occurred during the first 3 weeks of testing and were all due to improper gyroscope bearing preload. The fourth breakdown occurred near the end of testing. The gyro wheel normally spins in a sealed atmosphere of hydrogen and helium. During cold temperature testing, the epoxy seal broke, allowing air to enter and cause excessive drag on the gyro wheel.

b. Three breakdowns occurred in the electronic control unit. Two were caused by component failures of unknown cause. The other was caused by improper operation. The equipment is not fused, and the application of battery power with reversed polarity burned out some wiring and several components of the inverter.

c. The caging mechanism required modification during the test program. The upper band clamp did not consistently seat properly after caging. The seating surfaces of the upper band clamp were relapped, and instrument accuracy increased from 1.14 mils to 0.30 mil standard deviation.

d. The plate level of the theodolite did not always indicate functional level. The horizontal relationship of the theodolite level vial to the upper band clamp changed, causing the instrument to be leveled improperly, thus introducing azimuth errors.

e. The magnetic shield enclosing the gyro container was not firmly fastened to the gyroscopic reference unit housing, and on one occasion during the test it was inadvertently rotated. This caused a change in the magnetic field immediately surrounding the gyro container. The shield was reoriented to its former position and cemented into place.

f. One tripod leg clamp was broken by shearing the pin holding the clamp handle. This did not stop operation, but coarse adjustment of that tripod leg was impossible until the pin was replaced.

g. The gyro damping fluid leaked from its container on several occasions due to temperature change or tipping the instrument, requiring the addition of more fluid.

h. The instrument case and accessories withstood repeated handling and transportation without damage.

i. After the developmental problems encountered during the first part of the test were corrected, the equipment was operated over 300 hours with no breakdowns other than those due to improper operation and cold temperature.

ADEQUACY OF EQUIPMENT

TEST NUMBER 14

1. PURPOSE.

To determine the adequacy of the test item for normal field use.

2. METHOD.

The instrument was operated in five field locations and five indoor sites. Day and night observations were taken, and all accessories were used during testing.

3. RESULTS.

The test instrument was, in general, satisfactory for the intended use with the exception of the items listed in Appendix D and within the limitations described in Appendix C, Test Number 4.

APPENDIX D

DEFICIENCIES AND SUGGESTED MODIFICATIONS

(ESSENTIAL)

	DEFICIENCY	SUGGESTED MODIFICATION
1.	Relationship between theodolite level vial and upper suspension point of pendulous gyro unstable, causing loss of functional level of pendulous gyro.	Provide stable relationship between reference level vial and upper suspension point of pendulous gyro or eliminate problem by providing a suitable pivot for upper suspension point.
2.	Azimuth errors contributed by the caging and uncaging process.	Redesign caging mechanism to eliminate source of error.
3.	Vibration and shock can move the theodolite azimuth scale, causing calibration errors.	Provide clamp for azimuth scale.
4.	The gyroscopic reference unit must be oriented to within 10 mils of north.	Eliminate need for preorientation.
5.	Gyro container not suitably sealed for low temperature operation.	Provide sealing adequate for low temperature operation.
6.	Theodolite controls stiffen at low temperature.	Lubricate theodolite with grease conforming to MIL-G-10924.
7.	Wind causes azimuth errors.	Block entry of wind to interior of gyroscopic reference unit.
8.	Auxiliary equipment required to field check electrical circuits.	Provide switch and meter to show critical voltages.
9.	The carrying case does not provide shock and vibration protection for the gyroscopic reference unit.	Provide protection from shock and vibration.

	DEFICIENCY	SUGGESTED MODIFICATION
10.	Gyro damping fluid will leak under certain conditions.	Provide improved seal for fluid reservoir.
11.	Tripod legs can damage electronic control unit when equipment is being assembled for transport.	Redesign to prevent possibility of damage.
12.	Electronic circuits not protected by fuses.	Fuse all circuits.

(DESIRABLE)

	DEFICIENCY	SUGGESTED MODIFICATION
101.	Control panel not illuminated for night operation.	Provide adjustable illumination for all indicators and controls.
102.	Electronic control unit not waterproof.	Provide waterproofing.
103.	Pickoff adjustments and check of functional level require dummy load, soldering, special screwdriver, and removal of outer magnetic shield.	Provide simplified method of checking functional level and adjusting pickoff.
104.	Tripod coarse leveling clamps are flimsy.	Provide stronger clamps.
105.	Leveling screws not protected from weather and dirt.	Provide protective sleeves.
106.	Small Allen wrench required for removal of subassemblies.	Use conventional screws.
107.	Theodolite accessories for arctic operation not provided.	Provide winterization kit.
108.	Theodolite azimuth circle setting too easily changed by operating personnel.	Provide locking screw for circle setting knob or cover or remove knob.

	DEFICIENCY	SUGGESTED MODIFICATION
109.	Operation and Maintenance Manual is inadequate.	Provide complete instructions.
110.	No positive indication of caged or uncaged condition of gyroscope.	Provide obvious signal to indicate when gyro is uncaged.
111.	Electronic components not fungus or moisture resistant.	Provide properly coated or potted components.
112.	Controls not identified.	Provide markings to identify each knob, meter, switch, and connector by its functional name.
113.	Instrument does not have warning plates.	Mark instrument "Delicate Instrument" and "Do Not Move When Uncaged."
114.	Instrument not properly painted.	Paint in accordance with MIL-T-704, Type A.

APPENDIX E

EVALUATION OF LIGHTWEIGHT GYRO AZIMUTH THEODOLITE (LEAR) WITH RESPECT TO MILITARY CHARACTERISTICS FOR INERTIAL SURVEYING EQUIPMENT

MILITARY CHARACTERISTICS	EVALUATION
A. Short Range Weapons.	
1. The orienting device shall be tripod mounted and with tripod shall not exceed 50 pounds in weight. Associated electronic gear exclusive of power supply shall not exceed 30 pounds.	Complies.
2. The orienting device shall be an all-weather device, operable night and day, to be used for rapidly establishing direction of orienting lines accurate to ± 1.0 mil (± 0.5 mil desired) within 60° north to 60° south latitude and as accurate as feasible in other latitudes.	Complies.
3. The device shall be capable of determining the azimuth of an orienting line within 15 minutes (5 minutes desired) after arrival at a site.	Does not comply.
4. The preparation period required to place it in proper operating condition shall be the shortest practicable period and shall not exceed 10 minutes at an ambient temperature of 75° F.	Complies.
5. The optical sighting device shall be at least a 4-power telescope capable of being focused at distances from 3 meters to infinity.	Complies.
B. Long Range Weapons.	
1. The orienting device shall be tripod mounted and with tripod shall not exceed 200 pounds in weight, and by sectionalization, shall be man-portable. Associated electronic gear, exclusive of power supply, shall not exceed 30 pounds.	Complies.

MILITARY CHARACTERISTICS	EVALUATION
2. The long-range orienting device shall be an all-weather device, operable night and day, to be used for establishing the direction of orienting lines accurate to 0.1 mil within 60° north and 60° south latitude and as accurate as feasible in other latitudes.	Does not comply.
3. It shall be capable of determining the azimuth of an orienting line to the accuracy specified within 2 hours after arrival at a site.	Complies.
4. The optical sighting device shall be capable of sighting on well-defined objects at distances from 30 meters to 10 kilometers.	Complies.
C. General.	
1. The equipment shall be designed to provide rapid means for setting up in the field.	Complies.
2. Means shall be provided for plumbing the observing unit over a ground point.	Complies.
3. All operating controls and functions shall permit ease of manipulation when arctic gloves are worn.	Complies in part.
4. The equipment shall be capable of operating from either 115- or 220-volt, 60-cycle source.	Does not comply.
5. The equipment shall be treated for elimination of interference with radio communications.	(Not tested.)
6. The equipment shall withstand extended field use under conditions likely to be encountered in military service.	Does not comply.
7. All components shall be as lightweight and compact as practicable and shall be contained in suitable carrying cases, which shall provide protection from shock, dust, and moisture.	Does not comply.

MILITARY CHARACTERISTICS	EVALUATION
8. The equipment shall perform acceptably under all operating conditions per paragraphs 7a, 7b, and 7c of AR 705-15 and shall be capable of safe storage and transportation under conditions stated in paragraph 7d of AR 705-15.	Does not comply.
9. Air transportability is required in Phase II of airborne operations.	Complies.

Category 11 - Mapping and Geodesy

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Report 11-TR, 21 Feb 63, 67 pp, 17 illus
USAEGIMRADA Task 1S643315D57811
USATECOM Project 2-S-3020-01

Unclassified Report

Report covers the Engineering Tests of the Lightweight Gyro Azimuth Theodolite, Lear Model Number 11NG530A, performed at the GIMRADA test areas at Fort Belvoir, Virginia, and Fort Greely, Alaska. The test instrument was fabricated by Astronics Division of Lear Siegler, Inc., and consists of a theodolite mounted on a gyroscopic reference unit, a combined electronic control unit and carrying case, and a tripod. The instrument is powered by internal batteries, weighs 31 pounds 6 ounces, and after 20 minutes operation time will permit readout of azimuth to any target sighted through the theodolite telescope. Testing under various conditions demonstrated that accuracies of 0.38 mil (standard deviation) or better could be obtained with the instrument. Report concludes that the Lightweight Gyro Azimuth Theodolite (Lear) meets the objective and Military Characteristics set forth in Task 1S643315D57811 for short range weapons orientation except as noted in Appendix E, and upon correction of the deficiencies listed in Appendix D, the Lightweight Gyro Azimuth Theodolite (Lear) will be suitable for military field use.

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